START

WHC-SD-EN-RA-004
Revision 0

Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

THIS PAGE INTENTIONALLY
LEFT BLANK

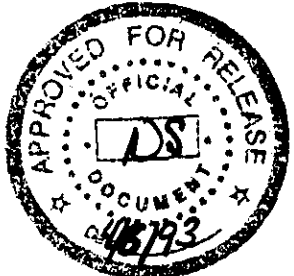| 2. To: (Receiving Organization) DISTRIBUTION	3. From: (Originating Organization) 100 AREA REMEDIAL INVESTIGATION	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: ER/81310	6. Cog. Engr.: J. M. AYRES	7. Purchase Order No.: N/A
8. Originator Remarks: RELEASE		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Impact Level	(G) Reason for Trans- mittal	(H) Origi- nator Dispo- sition	(I) Receiv- er Dispo- sition
1	WHC-SD-EN-RA-004		0	Qualitative Risk assessment for the 100-HR-1 Source Operable Unit	3Q	1	1	

16. KEY

Impact Level (F)	Reason for Transmittal (G)	Disposition (H) & (I)
1, 2, 3, or 4 (see MRP 5.43)	1. Approval 4. Review 2. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required)	1. Approved 4. Reviewed no/comment 2. Approved w/comment 5. Reviewed w/comment 3. Disapproved w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Impact Level for required signatures)

(G) Rea- son	(H) Disp.	(J) Name (K) Signature (L) Date (M) MSIN	(J) Name (K) Signature (L) Date (M) MSIN	(G) Rea- son	(H) Disp.
2	1	Cog.Eng. J.M. Ayres 3/31/93 H6-02	EDMC (2) H6-08	3	
2	1	Cog. Mgr. R.P. Henckel 3/31/93 H6-02	Central Files (2) L8-04	3	
2	1	QA G.S. Corrigan 3-31-93 H4-16	ERC H6-07	3	
		Safety	N. K. Lane H6-01	3	
		Env.	R. L. Biggerstaff H6-02	3	
3		A. D. Krug H6-02			
3		S. W. Clark H6-01			

18. J.M. Ayres 3/31/93 Signature of EDT Originator Date	19. Authorized Representative Date for Receiving Organization	20. R. P. Henckel 3-31-93 Cognizant/Project Date Engineer's Manager	21. DOE APPROVAL (if required) Ltr. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (07/91) GEF097

THIS PAGE INTENTIONALLY
LEFT BLANK

Date Received: 3/29/93	**INFORMATION RELEASE REQUEST**	Reference: WHC-CM-3-4

Complete for all Types of Release

Purpose		ID Number (include revision, volume, etc.)

Purpose				ID Number (include revision, volume, etc.) WHC-SD-EN-RA-004, Rev. 0

Purpose

[]	Speech or Presentation		[]	Reference
	[] Full Paper	(Check	[X]	Technical Report
	[] Summary	only one suffix)	[]	Thesis or Dissertation
	[] Abstract		[]	Manual
	[] Visual Aid		[]	Brochure/Flier
[]	Speakers Bureau		[]	Software/Database
[]	Poster Session		[]	Controlled Document
[]	Videotape		[]	Other

List attachments.

Date Release Required

March 30, 1993

Title: Qualitative Risk Assessment for 100-HR-1 Source Operable Unit	Unclassified Category UC- N/A	Impact Level 3Q

New or novel (patentable) subject matter? [X] No [] Yes
If "Yes", has disclosure been submitted by WHC or other company?
[] No [] Yes Disclosure No(s).

Information received from others in confidence, such as proprietary data, trade secrets, and/or inventions?
[X] No [] Yes (Identify)

Copyrights? [X] No [] Yes
If "Yes", has written permission been granted?
[] No [] Yes (Attach Permission)

Trademarks?
[X] No [] Yes (Identify)

Complete for Speech or Presentation

Title of Conference or Meeting
N/A

Group or Society Sponsoring

Date(s) of Conference or Meeting	City/State		

Will proceedings be published? [] Yes [] No
Will material be handed out? [] Yes [] No

Title of Journal
N/A

CHECKLIST FOR SIGNATORIES

Review Required per WHC-CM-3-4	Yes	No	Reviewer - Signature Indicates Approval		
			Name (printed)	Signature	Date
Classification/Unclassified Controlled Nuclear Information	[]	[X]			
Patent - General Counsel	[X]	[]	S W BERGLIN	*(signature)*	7/30/93
Legal - General Counsel	[X]	[]			
Applied Technology/Export Controlled Information or International Program	[]	[X]			
WHC Program/Project	[]	[X]			
Communications	[]	[X]			
RL Program/Project	[]	[X]			
Publication Services	[X]	[]	L. Hermann	S. Hermann	4/6/93
Other Program/Project	[]	[X]			

Information conforms to all applicable requirements. The above information is certified to be correct.

	Yes	No	INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP
References Available to Intended Audience	[X]	[]	Stamp is required before release. Release is contingent upon resolution of mandatory comments.
Transmit to DOE-HQ/Office of Scientific and Technical Information	[]	[X]	

Author/Requestor (Printed/Signature)   Date

J. M. Ayres *(signature)*   3/26/93

Intended Audience

[] Internal   [] Sponsor   [X] External

Responsible Manager (Printed/Signature)   Date

R. P. Henckel *(signature)*   3/26/93

Date Cancelled	Date Disapproved

THIS PAGE INTENTIONALLY
LEFT BLANK

SUPPORTING DOCUMENT		1. Total Pages 282

2. Title	3. Number	4. Rev No.
Qualitative Risk Assessment for 100-HR-1 Source Operable Unit	WHC-SD-EN-RA-004	0

5. Key Words	6. Author
Limited field investigation, Ecological evaluation, Human health evaluation, risk-based screening of soils	Name: J. M. Ayres

APPROVED FOR PUBLIC RELEASE
4/6/93 T. Jolls

Signature

Organization/Charge Code 81310/PE13B

7. Abstract

Ayres, J. M., 1993, *Qualitative Risk Assessment for 100-HR-1 Source Operable Unit*, WHC-SD-EN-RA-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed.

PATENT STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA.

DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

9. Impact Level 3Q

10. RELEASE STAMP

OFFICIAL RELEASE (11) BY WHC

DATE **JUN 17 1994**

Station #12

THIS PAGE INTENTIONALLY
LEFT BLANK

Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved for Public Release

THIS PAGE INTENTIONALLY
LEFT BLANK

EXECUTIVE SUMMARY

BACKGROUND

The Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE), signatories to the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement, Ecology et al. 1992), have developed the Hanford Site Past-Practice Strategy (HSPPS, DOE-RL 1992a) to emphasize initiating and completing waste site cleanups with a bias for action. This strategy relies, in part, upon the use of a qualitative risk assessment (QRA) to assist in decision-making. The QRA is performed using the Hanford Site Baseline Risk Assessment Methodology (HSBRAM) as guidance (DOE-RL 1993a). The results will be used, along with other considerations, to make a recommendation for or against an interim remedial measure (IRM) at each high-priority waste site. The objective of conducting IRMs at Hanford is to achieve cleanup and reduce risk in the shortest time possible and in a cost effective manner.

The QRA is an evaluation of risk for a predefined set of human and environmental exposure scenarios and is not intended to replace or be a substitute for a baseline risk assessment. It is streamlined to consider only two human health exposure scenarios (frequent-use and occasional-use) with four exposure pathways (soil ingestion, fugitive dust inhalation, inhalation of volatile organics from soil, and external radiation exposure) and a limited ecological evaluation. Evaluation of potential risk to groundwater associated with each high-priority waste site is addressed in the LFI. The exposure parameters used in the frequent-use and occasional-use exposure scenarios are identical to those presented in Appendix A of the HSBRAM (DOE-RL 1993) for residential and recreational exposure scenarios, respectively. However, the terms "occasional-use" and "frequent-use" are used to describe the exposure scenarios in the QRA because the QRA scenarios represent a general bounding of conditions for potential frequency of human site-use. This is based on agreements by the 100 Area Tri-Party Unit managers. For humans, risks that might occur under frequent- and occasional-use scenarios were included to provide a range of risk estimates using reasonable maximum exposure (RME) parameters as provided in HSBRAM. The ecological evaluation concentrates on the potential effects of contaminants on the Great Basin pocket mouse. The pocket mouse is used because its home range approximates the size of many waste sites, and these mice are a key part of the terrestrial food chain at the Hanford Site.

Data for the 100-HR-1 QRA were available from historical information and recent Limited Field Investigation (LFI) sampling data. The maximum concentration of each analyte detected above 15 ft at a waste site was selected from tabulated historical and LFI data for evaluation in the QRA. Constituents present below 15 ft will be evaluated in the LFI for potential impact to groundwater. Inorganic analytes were screened to determine contaminants by comparison with the 95 percent upper tolerance limit of the mean (UTL) for background soil data provided by *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE-RL 1993b). No organic and radionuclide analytes were screened by comparison to background, as there are no background values that have been agreed to by the Tri-Party signatories. Where contaminant levels were available from waste site sampling, risk calculations were performed.

RESULTS

This QRA evaluates a total of 13 high-priority waste sites as specified in the Remedial Investigation/Feasibility Study Work Plan for the 100-HR-1 Operable Unit (DOE-RL 1992b). Historical and recent LFI sampling data were available for evaluation of five waste sites. Historical

data only were used to evaluate another two of the 13 sites. The remaining six waste sites were evaluated using historical process information. Of these six sites, one has an analogous site in the 100-DR-1 operable unit which is referenced in the discussion of risk. Qualitative human health risks were categorized as high [Lifetime Incremental Cancer Risk (ICR)] > 1E-02, medium (ICR 1E-04 to 1E-02), low (ICR 1E-06 to 1E-04) and very low (ICR < 1E-06). Four of the seven sites with sampling data were rated as having a high human health risk potential under the frequent-use scenario in 1992. Two of the seven sites were rated as having a high human health risk potential under the occasional-use scenario in 1992. After decay of radionuclides was calculated to the year 2018, three of the four sites with high human health risk potential for frequent use still rated high. These sites are the 116-H-1 trench, 116-H-7 retention basin, and process effluent pipelines (sludge).

In general, the risk-driving pathway is external exposure to radionuclides. Specific radionuclides identified as key contributors to these overall risk estimates were cesium-137, cobalt-60, europium-152, and europium-154. Under current conditions, human intrusion into contaminated soils can be prevented such that the soil provides complete radiation shielding against gamma-emitting radionuclides more than 6 ft below ground surface. Even when accounting for this shielding effect, one of the seven sites was still rated as having a high human health risk (under the occasional-use scenario) because the maximum detected concentrations exist in the top 6 ft.

The ecological evaluation estimates the likelihood of an adverse effect occurring to wildlife. In the case of 100-HR-1 terrestrial wildlife, the risk assessment assumed that the key receptor organism, the Great Basin pocket mouse, was a frequent site user and was exposed to the maximum concentration of soil contaminant to a depth of 15 ft in an individual waste site. Two exposure scenarios were analyzed. The first uses the maximum soil contaminant concentrations from the upper 15 ft, which is an unlikely exposure scenario resulting in a conservative risk assessment. A second exposure scenario considers maximum soil contaminant concentrations from the upper 6 ft, representing a more likely exposure scenario. The results of the qualitative ecological evaluation are compared to established benchmarks to identify whether a waste site is a candidate for an interim remedial measure.

The ecological benchmark for radionuclides is a total internal dose of 1 rad/day. An ecological benchmark is a concentration/dose that is used as a threshold above which a receptor response is expected. Exceeding this value would indicate risk. The organism dose that exceeded this benchmark was classified as high risk. Four sites, the process effluent pipelines (sludge) at the 0-6 ft depth, the 116-H-1 trench, the 116-H-2 trench and the 116-H-7 retention basin (the latter three at both the 0-6 ft and 0-15 ft depths), indicate potential ecological risks from strontium-90. For the non-radiological benchmark, the wildlife NOEL were exceeded by arsenic, lead, and zinc in the 116-H-7 Retention Basin for both the 0-6 ft depths and the 0-15 ft depths. The NOEL was exceeded by arsenic in the 116-H-1 Trench (0-15 ft) and by barium, manganese, and vanadium in the 116-H-9 crib (both the 0-6 ft and 0-15 ft depths).

UNCERTAINTIES

Uncertainty exists in the results of the human health and environmental evaluations for the 100-HR-1 source operable unit because of uncertainties in the contaminant concentration data, in the assumptions of the exposure scenarios analyzed, and in the toxicity values for both human and ecological receptors. Where uncertainties exist, parameter estimates are generally biased in a conservative manner. Consequently, this QRA provides risk estimates which are biased toward the protection of human health and ecological integrity, considering the qualitative nature of the available data.

Identification of contaminants and concentrations are based on a limited sampling program and historical data of unvalidated quality. It is unlikely that the available data fully characterize many of the waste sites. Maximum representative (rather than average) concentrations are used in the risk evaluation due to the limited number and quality of waste site sample data. Additional uncertainty is introduced by assuming that contaminants are uniformly distributed across the waste sites when it is known that the LFI and historical sampling programs were intended to take "snapshots" of likely "hot spots" suspected of being contaminated based upon process knowledge.

The assumptions of the exposure scenarios and the risk evaluation itself lead to uncertainty in the application of the results, although the evaluation is meant to be an upper bound of potential risk. The two human health scenarios (frequent- and occasional-use) evaluated to provide estimates of hazard or risk do not currently occur in the 100-H Area. In the ecological risk evaluation no allowance is made for radioactive decay, bioavailability, or dilution effects.

There are uncertainties associated with the toxicity values used in both the human health and ecological risk assessments. These values are often based on limited acute animal studies with the effects extrapolated to the lower chronic dose levels associated with environmental contamination. Additional uncertainty is introduced by applying these values to humans or to animal species other than those evaluated in the studies."

THIS PAGE INTENTIONALLY
LEFT BLANK

LIST OF ACRONYMS

ARCL	Allowable Residual Contamination Levels
BGS	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act 1980
CLP	Contract Laboratory Program
COC	Contaminant of Potential Concern
DOE	U.S. Department of Energy
DOE-RL	United States Department of Energy, Richland Operations Office
Ecology	Washington Department of Ecology
EDMC	Environmental Data Management Center
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
HEAST	Health Effects Assessment Summary Tables
HEIS	Hanford Environmental Information System
HFSUWG	Hanford Future Site Uses Working Group
HI	hazard index
HQ	hazard quotient
HSBRAM	Hanford Site Baseline Risk Assessment Methodology
HSPPS	Hanford Site Past-Practice Strategy
ICR	Lifetime Incremental Cancer Risk
IRIS	Integrated Risk Information System
IRM	Interim Remedial Measure
ISV	in situ vitrification
LFI	Limited Field Investigation
LOEL	lowest observable effects level
MEI	Maximally Exposed Individual
ND	not detected
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NPL	National Priorities List
PAH	polyaromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEF	Particulate Emission Factor
QA	Quality Assurance
QBRAM	Qualitative Baseline Risk Assessment Methodology
QC	Quality Control
QRA	Qualitative Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactive
RfD	reference dose
RME	Reasonable Maximum Exposure
SF	slope factor
TAL	target analyte list
TCL	target compound list
TLD	Thermoluminescent Detector
TSD	Treatment, Storage and Disposal

LIST OF ACRONYMS (Cont.)

UCL	upper confidence limit
UTL	upper tolerance limit
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
WIDS	Waste Information Data System

CONTENTS

CONTENTS (Cont.)

CONTENTS (Cont.)

CONTENTS (Cont.)

CONTENTS (Cont.)

TABLES (cont):

CONTENTS (Cont.)

TABLES (cont):

1.0 INTRODUCTION

The 100-HR-1 operable unit is located within the 100 Area of the Hanford Site (Figure 1-1). The 100 Area of the Hanford Site was included on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

The Washington State Department of Ecology (Ecology), EPA, and the U.S. Department of Energy (DOE) are signatories to the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement, Ecology, et al., 1992). The signatories have developed a strategy to emphasize initiating and completing waste site cleanups in the Hanford Site Past-Practice Strategy (HSPPS, DOE-RL 1992a). The HSPPS identifies three paths to support this bias for action. The paths are an Expedited Response Action (ERA), and an Interim Remedial Measure (IRM), with or without a Limited Field Investigation (LFI).

The qualitative risk assessment (QRA) is intended to provide information, along with other considerations in the LFI report, to identify potential candidates for IRMs, although it may be used to support the other paths when agreed upon by the Tri-Party Agreement signatories. An IRM, as defined in the HSPPS, is "an on-site response conducted pursuant to CERCLA 40 CFR 300.430 involving interim remedial actions which are conducted at a CERCLA past practice operable unit at any time prior to initiation of final remedial action. Interim response measures can include Resource Conservation and Recovery Act (RCRA) interim measures as deemed appropriate by the parties." It should be noted that an IRM is intended to provide remedial measures as needed during the course of CERCLA activities, and may not in itself be a final remedy.

This report provides the qualitative risk assessments for the high priority waste sites associated with this operable unit. The application of the HSPPS at the 100-HR-1 operable unit is discussed in detail in the *Remedial Investigation/Feasibility Study Work Plan for the 100-HR-1 Operable Unit* (DOE-RL 1992b).

1.1 PURPOSE AND SCOPE OF REPORT

The purpose of the QRA at the 100-HR-1 operable unit is to focus on a limited set of human and environmental exposure scenarios in order to provide sufficient information to assist the Tri-Party signatories in making defensible decisions on the necessity of IRMs. Frequent- and occasional-use exposure scenarios are evaluated in the human health QRA to provide bounding estimates of risk, and are based on the residential and recreational exposure factors, respectively, presented in the *Hanford Site Baseline Risk Assessment Methodology* (HSBRAM, DOE-RL 1993a) as agreed by the 100 Area Tri-Party unit managers. Currently, there are no residential or recreational land uses in the 100-HR-1 operable unit. Ecological scenarios are evaluated using biological endpoints with ranges similar in size to the waste site. The Hanford Future Site Uses Working Group (HFSUWG) recommended the 100 Area be classified for unrestricted land use and listed four options for consideration (HFSUWG 1992). The options are: (1) Native American uses; (2) limited recreation, recreation-related commercial uses and wildlife; (3) B-reactor as a museum/visitor center; and (4) wildlife and recreation. None of the HFSUWG recommendations included residential use.

Available off-Hanford Site monitoring information indicates that overall Hanford Site risk to current off-site residents already meets the 10^{-4} to 10^{-6} EPA target risk levels. Therefore, 100-HR-1 waste sites, which contribute only a part of any off-site risks, also currently meet the target risk range. In addition, current Hanford Site personnel are sufficiently protected because access to the 100-HR-1 waste site is restricted by fencing, on- and off-site monitoring is conducted, and soil or gravel cover exists which reduces or eliminates the potential for exposure. Because these current protective measures may not exist in the future, the QRA evaluates contaminants detected in the soil at the waste sites. The contaminants detected from 0 to 15 feet were considered to be exposed at the surface because the Washington Administrative Code requires this assumption based on the potential depth of soil excavation for a basement (WAC 173-340-740(6)(c)). As part of the QRA, contaminants detected below 15 feet were evaluated for potential impact to groundwater. Risk calculations, however, were not performed for those contaminants detected below 15 feet.

The only other current risk scenario would be a trespasser at the site. The occasional-use scenario effectively addresses this pathway. It is, however, a conservative assessment of current risk because it includes the evaluation of soil ingestion/inhalation to contaminants that may be as deep as 15 feet below ground surface. This conservative approach was used because of the limited data set and because the QRA is a screening level, bounding risk assessment.

The available LFI and historical data are evaluated in exposure and toxicity assessments to determine the risks or hazards associated with each high-priority waste site in the 100-HR-1 operable unit. The QRA is conducted using the HSBRAM (DOE-RL 1993a) as guidance.

The QRA for the 100-HR-1 source operable unit is based upon limited historical and LFI sampling data, where available, describing the presence and vertical extent of contamination at individual high-priority waste sites. Where sampling data are not available, historical and process knowledge is used to identify potential contaminants.

1.2 REPORT ORGANIZATION

Four chapters, including this introduction, are presented in this QRA. Chapter 2.0 is an overview of the QRA evaluation process, Chapter 3.0 provides the human health and ecological evaluation of each high-priority waste site, Chapter 4.0 presents a summary of the major findings of the QRA and includes summary tables which identify key results of the QRA.

1.3 OPERABLE UNIT BACKGROUND

The Hanford Site is a 1,434-km^2 (560 mi^2) tract of land located in Benton, Franklin, and Grant counties in the south-central portion of the state of Washington. The 100-H Area is located in Benton County along the bank of the Columbia River in the north-central part of the Hanford Site, approximately 44 km (27 mi) north-northwest of the city of Richland, Washington, as shown in Figure 1-1. The 100-HR-1 operable unit is located in the northeast portion of the 100-H Area and covers approximately 40.5 hectares (100 acres). The 100-HR-1 operable unit lies primarily within the northeast quadrant of Section 18 of

township 14N, range 27E and is located within latitude 46 42' 30" and 46 43' 30" north and longitude 119 29' 00" and 119 28' 00" west.

The 100-H Area contains the H reactor and its operational support facilities. The H reactor, constructed after World War II, operated from 1949 through 1965, when it was retired from service. The 100-H Area is subdivided into the 100-HR-1 and the 100-HR-2 operable units. 100-H Area operable units are shown in Figure 1-2. The 100-HR-3 groundwater operable unit lies beneath the 100 D/DR and 100-H area. This QRA addresses only high-priority waste sites in the 100-HR-1 operable unit.

The geographical area associated with the 100-HR-1 operable unit contains waste units associated with the original plant facilities constructed to support H reactor operations. Chapter 2.0 in the 100-HR-1 work plan (DOE-RL 1992b) provides, in detail, the operations conducted in the 100-HR-1 operable unit. Figure 1-2 shows the approximate boundaries of the 100-HR-1 operable unit with respect to other operable units. Figure 1-3 is a map of the 100-HR-1 operable unit showing high priority wastes sites.

THIS PAGE INTENTIONALLY
LEFT BLANK
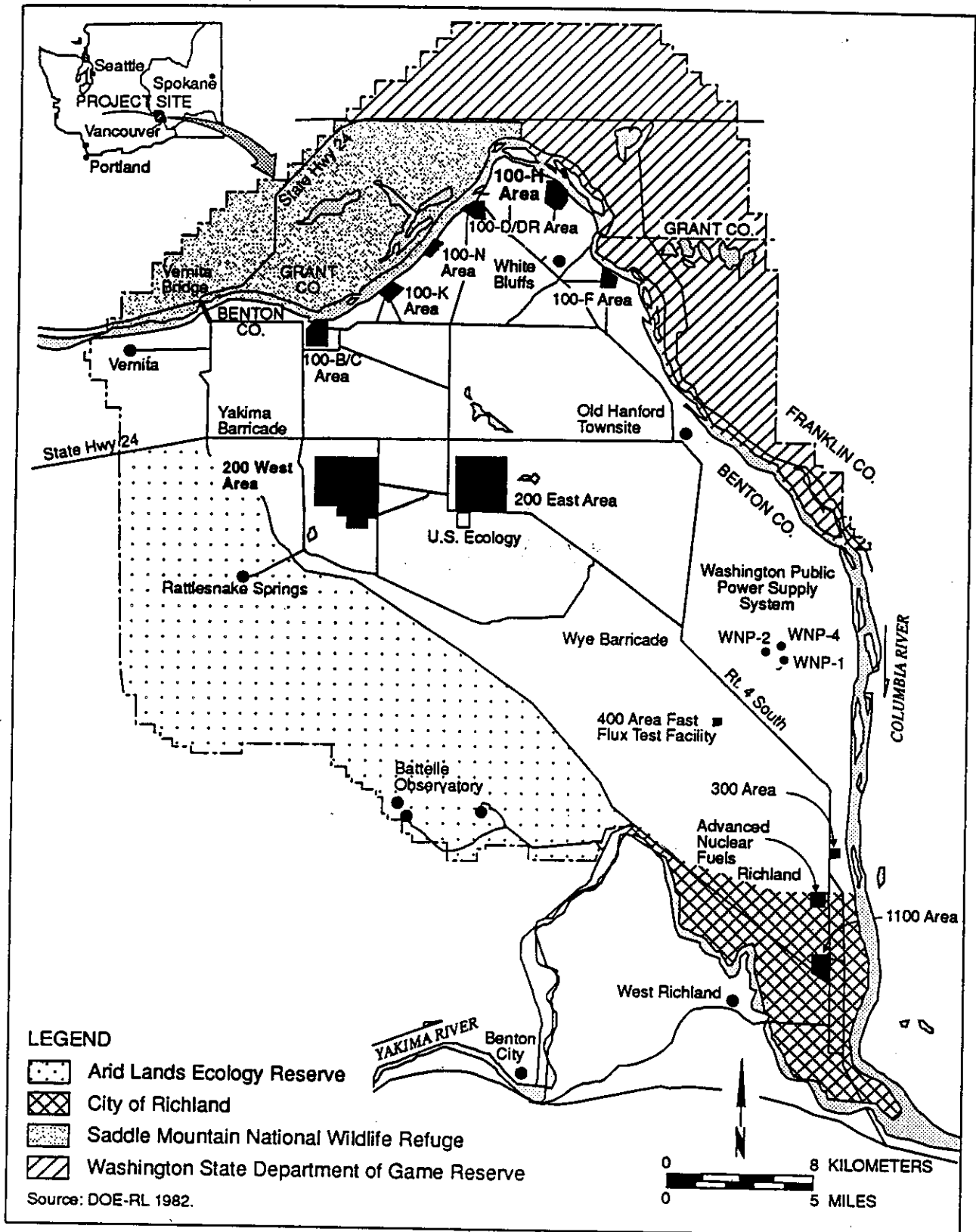
Figure 1-1. Location of 100-HR-1 Operable Unit at the Hanford Site

THIS PAGE INTENTIONALLY
LEFT BLANK
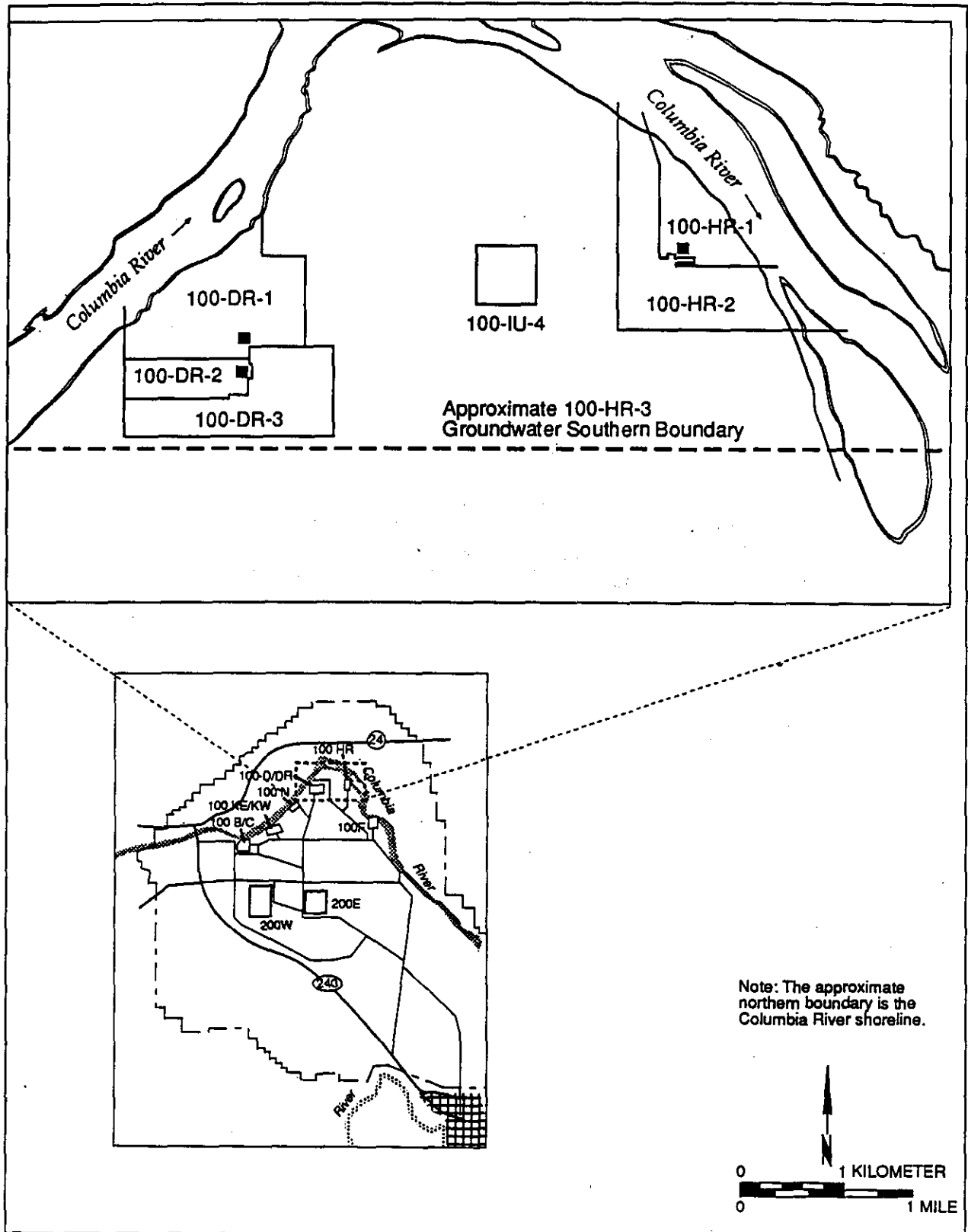
Figure 1-2. Map of the 100-D/DR and 100-H Areas Showing the Source and Groundwater Operable Units.

923 E007/44468/2-3-93

THIS PAGE INTENTIONALLY
LEFT BLANK

LEGEND:

☐ Existing Structure

▨ Demolished Building or Removed Facility

Ⓢ Septic Tank/Leachfield

– – ► Process Effluent Pipelines

Note: Facility locations and sizes are approximations.

923 E007/44481/7-1-93
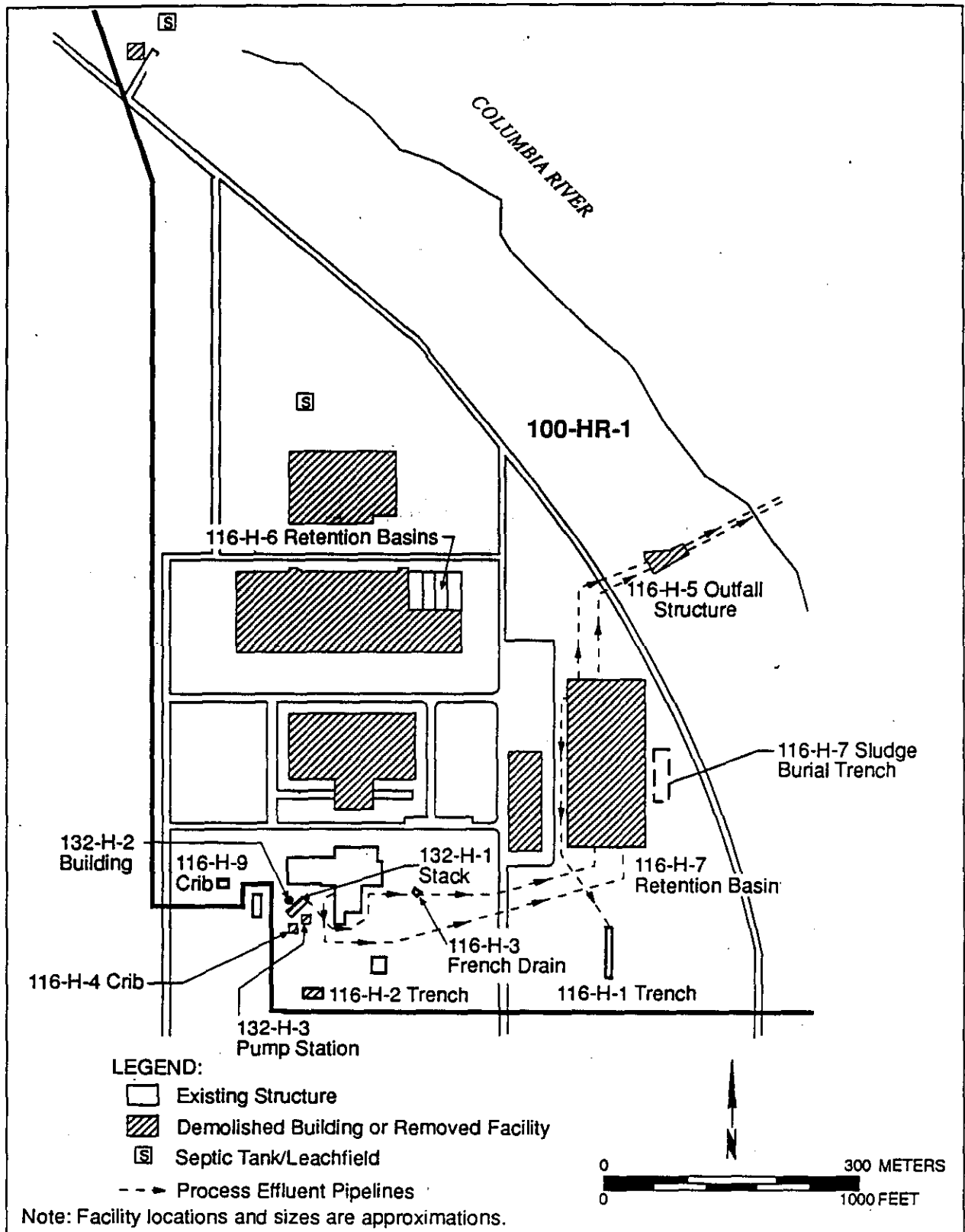
Figure 1-3. 100-HR-1 Operable Unit and the High Priority Waste Sites

THIS PAGE INTENTIONALLY
LEFT BLANK

2.0 HIGH-PRIORITY WASTE SITE EVALUATION OVERVIEW

This chapter provides an overview of the approach used in evaluating the high-priority waste sites for the 100-HR-1 operable unit QRA. Section 2.1 is a discussion of the data sources, Section 2.2 addresses the use of background, and Section 2.3 is an overview of the approach used to evaluate human health and ecological impacts. In addition, Section 2.3.3 addresses the approach used to evaluate potential groundwater impacts.

Table 4-2 in the 100-HR-1 operable unit work plan (DOE-RL 1992b) identified the high-priority waste sites to be included as a part of the HSPPS strategy. The sites for which LFI and historical data are available to conduct a QRA are:

- 116-H-1 trench
- 116-H-2 trench
- 116-H-3 french drain
- 116-H-7 retention basin
- 116-H-9 crib

The sites for which only historical data are available are:

- Process effluent pipelines
- 116-H-7 sludge burial trench

The site for which historical information and analogous site information are available is:

- 116-H-5 outfall structure

The sites for which there are limited historical information available are:

- 132-H-3 pump station
- 116-H-6 retention basin
- 132-H-2 building
- 132-H-1 stack
- 116-H-4 crib

Facilities proposed for decommissioning and low-priority facilities identified in Table 4-2 in the 100-HR-1 operable unit work plan will not be addressed in this QRA.

2.1 DATA SOURCES

The purpose of this section is to provide an overview of the general sources of information consulted to prepare the QRA. Historical data and LFI data were reviewed for the waste sites in Sections 2.1.1 and 2.1.2, respectively. A more comprehensive discussion of data sources is provided in the LFI report for this operable unit. The data for each high priority waste site are presented in Chapter 3.0.

2.1.1 Historical Data

A majority of the historical data (mainly Dorian and Richards 1978) that is summarized in Chapter 3.0 has been obtained from the 100-HR-1 operable unit work plan (DOE-RL 1992b), unless referenced otherwise. The historical data provide information on a waste site which is compared to LFI data, when available, to support identification of possible contaminants for consideration in the QRA and to support the characterization of the risk for the high-priority waste sites. The historical Dorian and Richards data are considered of medium quality. Although standard laboratory methods were used in sample analysis, the data were not validated. Radionuclide concentrations, in 1992 and 2018, are calculated, as appropriate, from historical data for use in the QRA

Former building sites may be potential sources of contamination, therefore, some decommissioned facilities have been included in the list of high-priority waste sites. Decontamination and decommissioning activities at some sites have been instituted to minimize the spread of radioactive isotopes from reactors, buildings and facilities after the reactors were retired. Decontamination and decommissioning data and information have been reviewed and included in the historical information if available.

2.1.2 LFI Data for the Waste Sites

The five high-priority waste sites at which LFI data were collected are:

- 116-H-1 trench
- 116-H-2 trench
- 116-H-3 french drain
- 116-H-7 retention basin
- 116-H-9 crib

The LFI data available for each operable unit include information from borehole, test pit, surface soil, or sludge samples that were collected where existing data were considered insufficient. Sampling and field activities for the 100-HR-1 operable unit are summarized in *Description of Work for the 100-HR-1 Source Operable Unit* (Roberts 1991). Figure 2-1 shows the LFI sampling locations within the 100-HR-1 operable unit. Samples were typically analyzed for volatile, semivolatile, pesticide/PCBs, radionuclides, and wet chemistry parameters as specified in Table 4-2 of the 100-HR-1 operable unit work plan (DOE-RL 1992b). Laboratories performing the analyses were Weston Analytics of Lionville, Pennsylvania and TMA-Norcal Laboratory of Richmond, California.

A total of 20 LFI samples were collected during 1992 at the 100-HR-1 operable unit. The LFI data collected for each waste site were analyzed using methods specified in Appendix A of the Quality Assurance Project Plan in the 100-HR-1 work plan. Based on the validation activities, data results were assigned qualifiers in accordance with criteria specified in the *Data Validation Procedures for Chemical Analyses* (Bechtold 1992). Data that are termed "usable" (detected compounds or estimated "J" values) can be used in the risk assessment. An example of data that are not considered usable are data that were rejected (qualified with an "R") by the data validator. If upon review of the rejected data, the reason for rejection was due to administrative concerns (e.g., missing data sheets) and not because of other quality assurance/quality control (QA/QC) issues (e.g., technical concerns), the rejected data are used in the QRA. This is the only instance in which rejected data were considered in the QRA.

The LFI data used in this report were 100% validated. Historical data have not been validated according to the same EPA guidelines.

Analytical results were compiled into tabular summaries for use in preparing the QRA. Data sources were electronic files in CLP format, validation reports, and laboratory result forms. Electronic files were processed to extract the analytical results. Data from validation reports and laboratory forms were hand entered, 100% verified, and corrected if needed in the tabular summaries. Data from all sources were compiled into separate tabular summaries of organic, inorganic, radiochemistry, and wet chemistry data and updated with qualifiers from the validation reports, where appropriate.

Laboratory and field blanks were used to evaluate each data set for common laboratory contaminants and site conditions. Organic laboratory blank results accompanying sample results for 100-HR-1 operable unit were used in conjunction with the five and ten times rule as specified in the *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*, section IV (Bleyler 1988). Results from organic field blanks collected at 100-HR-1 were used to evaluate the results from 100-HR-1 samples using the five and ten times rule specified in Bleyler (1988). A discrepancy exists between Bleyler (1988) and Bechtold (1992) in that the former document makes no distinction between the use of laboratory or field blanks while the later document specifies that the field blanks be treated separately using only the five times rule for all analytes. Inorganic and radionuclide field blanks were utilized using the five times rule as specified in Bleyler (1988). LFI data are of high quality based on the above information. Further discussion on laboratory and field blanks is provided in Appendix G.

A common data set is being used for the QRA and the LFI report.

2.2 GENERAL HANFORD SITE BACKGROUND DATA SUMMARY

The natural composition of soils at the Hanford Site has recently been characterized (DOE-RL 1993b). The characterization effort involved the determination of the types and concentrations of non-radioactive analytes that exist naturally in soils at the Hanford Site. In addition, physical properties and factors that might affect the natural soil chemical composition, as determined by regulatory protocols, were also characterized.

Project-specific background data have not been collected for the 100-HR-1 LFI and QRA, therefore the site-wide approach to characterization of soil background was used as recommended in HSBRAM (DOE-RL 1993a). The site-wide approach is based on the premise that all waste sites are part of a common sequence of vadose zone sediments, and the basic characteristics that control the chemical composition of the sediments are similar throughout the Hanford Site. Based on this premise, a range of natural soil compositions was used to establish a single set of soil background data. This approach has the advantage of providing a single, consistent set of data for assessing baseline risk. There may be instances, however, where a project-specific background may be a more appropriate comparison. It has been determined that there are soils in ecosystems (e.g. riparian ecosystems) that have distinctively higher concentrations of metals than the site-wide reference levels (DOE-RL 1993b). These higher concentrations were attributed to higher concentrations of organic matter in soils found in riparian ecosystems. Thus, it may be more appropriate to develop a project-specific background to evaluate waste sites that are located in the riparian ecosystem (e.g. outfall

structures). Although this approach should be evaluated further, it has not been used in this report.

The 95% upper threshold limit (UTL), based on a lognormal distribution of the data in DOE-RL (1993b), for inorganic analytes is presented in Table 2-1. The UTL is the 95% confidence limit for the 95th quantile of the distribution and serves as a statistically significant estimator on the upper population limits of background concentration. To determine if an inorganic analyte is a contaminant, the maximum value found in either historical or LFI data is compared to the 95% UTL which is used as the background value. If the analyte maximum concentration exceeds the 95% UTL, the analyte was considered a contaminant and evaluated further in the risk assessment. Detected levels of organic and radionuclide analytes in historical or LFI data are not compared against background. Instead, organic and radionuclide analytes are assumed to be contaminants and evaluated in the risk assessment, as recommended in HSBRAM (DOE-RL 1993a).

2.3 QUALITATIVE RISK ASSESSMENT OVERVIEW

As described in Section 1.1, the intent of the QRA is to provide information to be used in the LFI report in support of a decision whether an IRM is necessary at each high-priority waste site. The results and conclusions of the QRA for each high-priority waste site are presented in the text and tables of Chapter 3, and summarized in the text and tables of Chapter 4.

2.3.1 Human Health Evaluation

This section discusses the general approach used to implement the four elements of the human health evaluation for the QRA. Additional discussion on the QRA is presented in Appendix C of the HSBRAM (DOE-RL 1993a).

2.3.1.1 Identification of Contaminants of Potential Concern. The information on each high-priority waste site is reviewed to identify chemicals or radionuclides that may impact the key media (e.g., soil, groundwater, surface water, air, or biota). This information includes process knowledge, disposal knowledge, records of inventory, historical information, information obtained during site reconnaissance, and data generated from LFI sampling activities. Information or data collected from analogous sites or similar categories of sites (e.g., cribs associated with the reactor sites) may also be used to identify potential chemicals or radionuclides present at a site.

In general, both the historical and LFI data are considered for identification of contaminants of potential concern. The parameters are considered only if they are located in the upper 4.6 m (15 ft) of soil. The higher concentration for each parameter from either the historical or LFI data sets is selected for evaluation in the QRA.

The process discussed in Section C.2.1 of the HSBRAM (DOE-RL 1993a) and shown in Figure 2-2 is used to identify contaminants of potential concern for each high-priority waste site. This process includes the definition of contaminants based on site-wide background (see Section 2.1.3 (DOE-RL 1993a)) and the preliminary risk-based screening (see Section 2.1.4 (DOE-RL 1993a)) using residential scenario exposure parameters at a lifetime incremental cancer risk (ICR) of 1E-07 and a hazard quotient (HQ) of 0.1. Preliminary risk-based screening is used to identify potential risk-driving contaminants and to save time and resources in the review and implementation of the risk assessment.

If no LFI sampling data are available, the historical information discussed above is used to qualitatively develop a list of contaminants of potential concern for a site. Analogous site data may also be used to identify contaminants of potential concern.

2.3.1.2 Exposure Assessment. The exposure assessment methodology is presented in Section 2.2 and Appendices A and C of the HSBRAM (DOE-RL 1993a). The exposure assessment includes the determination of exposure scenarios, exposure pathways, exposure parameters, exposure point concentrations, and the quantification of exposures. The scenarios and pathways for the QRA have been discussed and selected by the 100 Area Tri-Party unit managers. The components of the exposure assessment methodology are individually discussed in the following paragraphs.

2.3.1.2.1 Exposure scenarios. The exposure scenarios selected to evaluate the high priority sites are based on frequent use and occasional use of the waste site under contaminant conditions in 1992. The exposure parameters used in the frequent-use and occasional-use exposure scenarios are identical to those presented in Appendix A of the HSBRAM (DOE-RL 1993) for residential and recreational exposure scenarios, respectively. However, the terms "occasional-use" and "frequent-use" are used to describe the exposure scenarios in the QRA because the QRA scenarios represent a general bounding of conditions for potential frequency of human site-use. Currently, there is no regular use of the high-priority waste sites in 100-HR-1 operable unit. Thus, the exposures and associated risks presented in the QRA in 1992 are not actual risks but estimates of potential risks under high-frequency use or low-frequency use. In addition to the above scenarios, the frequent-use scenario is also evaluated for radionuclides using the maximum concentration of radionuclides decayed to 2018. In accordance with the Tri-party agreement, the year 2018 is the earliest time in which the Federal Government could release portions of the Hanford Site for non-industrial uses. This additional scenario is presented to evaluate the impact of radionuclide decay on exposures that would occur in the future.

For the purpose of evaluating external exposure to radionuclides, an additional occasional-use exposure scenario is presented in Appendix F. This evaluation recognizes that contaminants that are located at depth are not accessible to receptors. However, radionuclides present in the soil could result in external exposures. Consequently, a more realistic evaluation of current exposures accounting for the presence of any clean cover is discussed for the occasional-use scenario in 1992 focusing on the external exposure pathway.

2.3.1.2.2 Exposure Pathways. The pathways that are evaluated for each scenario of the QRA for 100-HR-1, are:

- Soil ingestion
- Fugitive dust inhalation
- Inhalation of volatile organics from soil
- External radiation exposure.

No additional pathways are evaluated in this QRA. No modeling of contaminant transport has been conducted for the QRA of high-priority waste sites at 100-HR-1 operable unit.

2.3.1.2.3 Exposure Parameters. Scenario-specific exposure parameters are defined in Appendix A of the HSBRAM (DOE-RL 1993a). Recreational exposure parameters are used to evaluate the occasional-use scenario and are provided in Tables A-4, A-5, and A-6 of Appendix A of the HSBRAM (DOE-RL 1993a); residential exposure parameters are used to evaluate the frequent-use scenario and are provided in Tables A-7, A-8, and A-9 of Appendix A of the HSBRAM (DOE-RL

1993a). The QRA uses maximum contaminant concentrations, as discussed in Section 2.3.1.2.4, to conservatively evaluate a focused set of receptors and exposure pathways.

2.3.1.2.4 Exposure Point Concentrations. For purposes of the QRA, if contaminant concentration data are available, the maximum concentration of a contaminant of potential concern detected in a specific medium is used as the exposure point concentration. The maximum concentration is used, rather than calculating a 95% upper confidence limit of the mean (UCL), because of the limited number of samples that are available for each specific high-priority waste site and because this is a qualitative evaluation of the potential risk.

For waste sites with LFI and historical data, historical radionuclide sampling data concentrations were decayed to 1992, compared to LFI data, and the maximum concentrations between the two data sets used for evaluation in the QRA for frequent and occasional-use scenarios. LFI and historical sampling data were both decayed to 2018 to assess a frequent-use scenario in the future.

For waste sites with historical data only, the historical radionuclide sampling data concentrations were decayed to 1992 and evaluated for frequent- and occasional-use scenarios, and were decayed to 2018 to assess a frequent-use scenario.

The Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., constructing a basement) is from ground surface to 4.6 m (15 ft) below ground surface [WAC 173-340-740 (6(c)]. Therefore, for the soil ingestion or external exposure pathways, the maximum concentration of a contaminant detected in the upper 4.6 m (15 ft) of the soil is used to calculate contaminant intakes for the frequent-use and occasional-use scenarios in 1992 and the frequent-use scenario in 2018.

The methodology used to evaluate the effect of shielding on risks to occasional users because of the presence of clean cover in 1992, is provided in Appendix F. Maximum contaminant concentrations in the upper 2 m (6 ft) and site radiological survey data are used to evaluate potential risks at individual waste sites. Radionuclides present below 2 m (6 ft) do not present an external radiation exposure risk at concentrations encountered in this QRA.

Concentrations at greater depth, although not likely to result in exposures through soil ingestion, inhalation, or external exposure pathways, may impact groundwater. Discussion of potential impacts to groundwater from soil contaminants present at 100-HR-1 high-priority waste sites are presented within each site-specific QRA.

For the air inhalation pathway, maximum contaminant concentrations in the upper 4.6 m (15 ft) of soil and a respirable particulate emission factor (PEF), as described by EPA (1991a) were used to generate preliminary risk-based soil concentrations for fugitive dust inhalation. The PEF relates contaminant concentrations in soil to the concentration of respirable particles in the air due to fugitive dust emissions. The PEF of $2E+07$ m^3/kg used in the QRA is based on the National Primary Ambient Air Quality Standard for particulate matter of 50 μg/m^3 and the assumption that 100% of the particulates are retained in the lungs and absorbed. The PEF calculation is provided in Appendix C. A site-specific PEF was not calculated for each high-priority site due to the qualitative nature of the assessment.

2.3.1.2.5 Quantification of Exposures. The methodology for quantification of exposures is presented in Section 2.2.5 of the HSBRAM (DOE-RL 1993a). Equations used to estimate intakes (a measure of exposure expressed as the concentration that is contacted over a period of time) are also provided in Section 2.2.5 of the same document. Standard EPA equations (EPA 1989a, DOE-RL 1993a) are used as the basis for all intake calculations. Example equations and calculations are provided in Appendix C.

2.3.1.3 Toxicity Assessment. The general procedures for toxicity assessment are presented in Section 2.3 of the HSBRAM (DOE-RL 1993a). The toxicity assessment for the QRA identifies contaminant-specific toxicity factors and briefly discusses the key toxicities associated with the contaminants of potential concern. The intention is to include sufficient information on the contaminants of potential concern to assist project managers in reaching decisions on IRMs, but not to evaluate all potential toxicities or contaminant characteristics. Toxicity profiles for all contaminants of potential concern in the QRA for the 100-HR-1 operable unit are provided in Appendix B.

Several assumptions have been made with respect to the toxicity of parameters evaluated in the QRAs. These assumptions are:

- All chromium is assumed to be chromium (VI), which is the most toxic valence state of chromium;

- Site-wide background for antimony is based only on a detection limit. Because this detection limit was greater than the detection limit of the LFI data, all antimony is evaluated in the preliminary risk-based screening rather than eliminated from further evaluation by comparison to background;

- Nickel, as nickel subsulfide, and nickel refinery dust (about 50% nickel subsulfide) have been determined to be carcinogenic in humans via inhalation. Nickel refinery dust is generated during high temperature operations at manufacturing plants. Because there was no pyrolytic activity at these waste sites that would generate nickel refinery dust, detected nickel in environmental medium is, therefore, not considered carcinogenic;

- Because there is no published toxicity value for lead, it is not evaluated in the QRA beyond the preliminary risk-based screening if the concentration is within or less than the range of 500 - 1,000 mg/kg identified by EPA as generally protective for residential (i.e, frequent) use (EPA 1989b);

- If toxicity factors are not available for a contaminant, surrogate factors are generally not used in the QRA. Exceptions are appropriately noted. For example, because consensus on the appropriate manner of evaluating carcinogenic PAHs other than benzo(a)pyrene has not been reached in EPA Region 10, these compounds are not quantitatively evaluated in the QRA. This assumption may result in an underestimation of total waste site hazard quotients or total waste site incremental cancer risks; and

- When historical data do not identify which uranium isotope was detected, uranium-238 is assumed based on its weight percent contribution to natural uranium (approximately 99%). The slope factors of all uranium isotopes differ slightly, which may result in different risk estimates.

2.3.1.4 Risk Characterization. The risk characterization for the QRA is conducted as presented in Section 2.4 of the HSBRAM (DOE-RL 1993a). The qualitative approach evaluates sites with quantitative sampling data and sites with limited or no sampling data. Consequently, risk characterization is discussed separately for each situation in the following paragraphs.

2.3.1.4.1 Risk Characterization When Quantitative Data Are Available. If quantitative data are available for calculating lifetime incremental cancer risks (ICRs) and hazard quotients (HQs), the risk characterization includes:

- Calculation of contaminant-specific ICRs and HQs as described below;

- Calculation of site-specific risks from contaminant-specific risks;

- Qualitative discussion of the risks with respect to the following levels:

    Contaminant-specific ICR = 1E-06,
    Contaminant-specific hazard quotient = 1,
    Site total ICR = 1E-06, and
    Site total hazard index (i.e., sum of hazard quotients) = 1;

- Categorization of human health risks using the relative risk classifications of high (ICR > 1E-02), medium (ICR 1E-02 to 1E-04), low (ICR 1E-04 to 1E-06), and very low (ICR < 1E-06).

- Qualitative discussion of the uncertainty associated with the risk estimates ; and

- Qualitative discussion of the threat posed by the site.

Throughout the QRA, ICR values that exceed 1E-02 are reported as " > 1E-02" because the linear equation used to estimate cancer risk is only valid at low risk levels [(i.e., below estimated risks of 1E-02) EPA 1989a]. Risk estimates made using this equation become increasingly inaccurate as they approach a value of 1 because the stochastic nature of cancer induction implies that no exposure level is high enough to ensure a carcinogenic response. Therefore, in such cases ICR values are reported as " > 1E-02".

For noncarcinogenic contaminants, the HQ is:

HQ = Daily Intake / RfD

where the RfD is the contaminant-specific chronic reference dose.

For carcinogenic contaminants, the equation used to estimate the ICR is:

ICR = Intake X SF

where the SF is the contaminant-specific slope factor.

2.3.1.4.2 Risk Characterization When Quantitative Data Are Not Available. For six sites listed in Section 2.0, sampling data are not available to calculate ICRs and HQs. The risk characterization, therefore, is only a qualitative discussion of the threat posed by the site and the confidence in the information available to assess the threat. Process knowledge, data from analogous sites, and other information, as available, are utilized to qualitatively characterize the risk for a site.

Contaminant specific risk-based concentrations in a medium can be calculated if information is available on possible contaminants at a high-priority waste site. The risk-based concentrations are then compared to estimated site concentrations in a medium. The comparison of risk-based concentrations to estimated medium concentrations is a means of putting site information into perspective. For example, if historical data or process knowledge indicate that very high concentrations of contaminants may be present in the soil, the calculation of a risk-based soil concentration provides a means for identifying concentrations that would be of concern.

The basic intake equations are modified to identify concentrations in a medium associated with a given cancer risk or HQ using the HSBRAM (DOE-RL 1993a) exposure parameters. The basic equations modified appropriately are presented in Appendix C.

The risk characterization includes a qualitative discussion of the site information, the risk-based concentration comparison, and the potential threat posed by the site. The overall uncertainty in the risk characterization is an important part of the QRA, and is especially relevant when data are not available.

2.3.1.5 Evaluation of Uncertainty. The evaluation of uncertainty in the characterization of risks is an integral part of the QRA. The risks, both carcinogenic and noncarcinogenic, presented in the QRA are conditional estimates given multiple assumptions about exposures, toxicity, and other variables. The uncertainty in the QRA risk characterization focuses on specific uncertainties related to the waste·site (e.g., data evaluation) and to the risk assessment process (e.g., toxicity information, exposure assumptions, etc.).

Uncertainty can be related to the characterization of the waste site due to the quality of data used in the QRA. Confidence in the identification of contaminants and concentrations is rated high, medium and low and defined as follows:

- High: the waste site generally has historical and LFI data (either from the site or analogous data) of the same medium, i.e historical and LFI soil data.

- Medium: the waste site generally has historical and LFI data which is not of the same medium.

- Low: the waste site generally has historical data or information but no LFI data.

Data used in this QRA are generally of high, known quality (LFI data) or medium quality (Dorian and Richards data). LFI data are analyzed following specific EPA methods, have been validated following EPA functional guidelines, and are of known quality. The data used from the Dorian and Richards report were analyzed following routine laboratory protocols, but have not been validated, therefore the quality of the data is rated medium. Specific uncertainty considerations are discussed in Chapter 3.0 as part of each high-priority waste site QRA. An overall uncertainty discussion is presented in Chapter 4.0.

The uncertainties related to the risk assessment process are due to the appropriateness of the toxicity information, the interpretation of toxicity data, the exposure assumptions, and the risk characterization. The primary source of uncertainties related to the toxicity of the contaminants include the following:

- Using information on dose-response effects from high-dose exposure scenarios to predict effect at low-dose exposure scenarios.

- Using animal dose-response data to predict effects in humans.

- Using short-term exposure data to extrapolate to long-term, or vice versa.

- Using dose-response information from a homogeneous animal or healthy human population to predict the effects that may occur in the general population where there are varying sensitivities to different contaminants.

Uncertainty in the exposure assessment occurs because of the limited amount of data used in characterizing the exposure concentration. The use of maximum concentrations for soil exposures and assumed concentrations for air exposures may over- or under-estimate exposures. Additional uncertainty is present in the external exposure.assumptions and risk characterization, as discussed in Appendix F.

Uncertainty in the risk characterization is the result of adding multiple contaminant exposures over several pathways. The summation of cancer risks across pathways or for multiple pathways may make the total cancer risk estimate more conservative. However, some contaminants may not have been evaluated because of the lack of slope factors or reference doses or because analytical data were not available.

2.3.2 Ecological Evaluation

The qualitative ecological risk assessment estimates the ecological risk from existing contaminants in the 100-HR-1 operable unit to selected ecological receptors. The Great Basin Pocket Mouse is the indicator ecological receptor of risk from each of the waste sites within the 100-HR-1 operable unit. The mouse is used as the indicator receptor because it's home range is comparable to the size of most waste sites and will receive most of it's dose from a waste site.

2.3.2.1 Problem Formulation. Issues relevant to evaluating the qualitative ecological risk for waste sites within the 100-HR-1 operable unit are:

- identifying the contaminants of concern that occur in concentrations greater than background

- identifying the media in which these contaminants occur

- obtaining transfer coefficients for contaminant movement between indicator organisms

- estimating doses, daily intake rates, or body burdens from contaminants based on transfer coefficients, the conceptual model, fraction of the receptor's habitat that is contaminated, and exposure duration and frequency

- comparing doses, daily intake rates, or body burdens to established benchmarks.

2.3.2.1.1 Stressor Characteristics, Ecosystems Potentially at Risk, and Ecological Effects. This section describes the process of identifying the stressor characteristics, the ecosystems likely to be affected by these stressors, and the possible results to the stressor from exposure of selected ecosystem receptors.

The stressors of concern are identified in the human risk assessment as those constituents elevated above background. Those stressors above the background screen are used in the QRA. A detailed discussion of stressor characteristics is not given since all contaminants exceeding background are included in the risk assessment.

All contaminant elements evaluated in this analysis have been found in the soil within the site or were identified through historical records. The waste site does not contain surface water bodies and is not apparently subject to mass flows from surface water runoff. No data have been obtained to evaluate concentrations of contaminants in biological media within the site; consequently, biological uptake was evaluated from a soil source term.

Components of the 100-HR-1 operable unit environment that may be affected by wastes at the site include parts of the food web shown in Figure 2.3. For this qualitative risk assessment, only one receptor (the Great Basin pocket mouse, a herbivore) was chosen for risk screening. This is in contrast to a baseline risk assessment where multiple receptors and their risks are determined from site-specific data. A listing of plants, animals, birds, and reptiles found in proximity to the 100-HR-1 sites is available in Landeen et al. (1993). The reference also lists threatened and endangered plant and animal species native to Hanford. Information on 100 Area biotic sampling can be found in Schmidt et al. (1993), Landeen et al. (1993), and Wintczak (1993). A summary table of measured biotic uptake of contaminants by plants near the 100-HR-1 waste sites is included in the Appendix (Table D-4) and can serve as potential verification data for the soil-based uptake model of radionuclides.

Contaminants found in the soil at waste sites within the 100-HR-1 operable unit include radioactive and nonradioactive elements. For nonradioactive elements, ecological effects were evaluated from uptake from the soil by plants, and by accumulation of these elements through the foodweb. Radioactive elements have ecological effects resulting from their presence in the abiotic environment (external dose), and from ingestion (consumption dose), resulting in a total body burden. Total daily doses to an organism can be estimated as the sum of doses received from all radioactive elements ingested, residing in the body, and available in the organism's environment. Radiological dose calculation methodology has been reviewed by Baker and Soldat (1992), and was applied in this risk assessment. The radiological dose any organism receives is usually expressed as rad/day.

2.3.2.1.2 Endpoint Selection. The measurement endpoints are the health and mortality of the Great Basin pocket mouse. Assessment endpoints are beyond the scope of the QRA, since it is not an ecosystem level study. Thus, the focus of this study is at the individual level of ecological organization. The major departure of the qualitative and quantitative risk assessments occurs at endpoint assessments. Typically, in a quantitative risk assessment, several trophic levels and several ecological receptors of the foodchain are selected for study to encompass receptors of varying sensitivity, different endpoints, and several contaminant transport pathways. For this qualitative ecological risk assessment, only one receptor is used for limited exposure scenarios and simple endpoints.

2.3.2.1.3 The Conceptual Model. Based on the descriptions of ecological resources present at or near the 100-HR-1 operable unit wastes site and assuming a contaminant source limited to the soil, a conceptual ecological model can be derived for the key ecological resources (Figure 2-3). In this model, uptake of contaminants from soil by vegetation serves as the basic source of contaminant entry into the food chain. External doses of ionizing radiation, inhalation of contaminants, and ingestion via preening or grooming contaminated fur are ignored in this model. The herbivore component, represented in the model by insects, the dominant herbivorous mammals, and the dominant herbivorous (seed-eating) bird, acts as the primary conduit between contaminants in vegetation and contaminants in carnivores. Two levels of carnivores are common to the 100 Area: the primary carnivores prey almost entirely on herbivores, consequently only three levels of bioaccumulation are possible (soil to plant, plant to herbivore, herbivore to primary carnivore). Second-order carnivores prey on other carnivores as well as on herbivores. The key receptor evaluated in this risk assessment is the Great Basin Pocket Mouse.

Estimating ecological risks from contamination is problematic when considering animals whose habitat use extends beyond the operable unit boundaries. For example, the 116-H-1 waste site is a relatively small area within the much larger 100-HR-1 operable unit, and the other waste sites are separated from each other by areas where contaminant concentrations are unknown, but are likely to be much lower than that found in the waste sites themselves. Consequently, the environment outside the 100-HR-1 operable unit waste site as used by most of the wide-ranging animals in the conceptual model is likely to be a mix of contaminated and uncontaminated habitat.

Because the waste site is small, when compared to the home ranges of animals such as hawks, owls, loggerhead shrikes, and coyotes, the increase in risk from an individual waste site to these resources from the operable unit is likely to be small. This risk increase may be insignificant if an uncontaminated environment outside the operable unit is assumed. A worst case assumption would be that the contaminated environment of the receptor outside the waste site is not much different from that within the site environment. Such an assumption would be highly conservative for the larger raptors and the coyote, who range over many square kilometers (miles). A reasonable estimation of risk for these receptors lies somewhere between these extremes. The approach taken in this QRA is to evaluate risk for the small herbivore component (Great Basin Pocket Mouse) based on a two-step accumulation model operated on a waste-site-by-waste-site basis, since each waste site approximates the size of the Great Basin Pocket Mouse home range. The home range of the Great Basin pocket mouse varies from 508-4005 sq m for parts of the Hanford Site (O'Farrell et al. 1975).

2.3.2.2 Analysis Phase. The analysis phase uses the available data to assess the potential of exposure of the Great Basin Pocket Mouse to the stressors at each waste site.

2.3.2.2.1 Characterization of Exposure. The section focuses on developing the exposure relationship between receptor and site contaminants. It is assumed these concentrations were uniformly distributed over the site and were biological active and available for transport into the biosphere. It is also assumed that the measured concentrations for the radionuclides were the concentrations appropriate at the time of the risk assessment.

The spatial distribution or the home range of the pocket mouse was evaluated from available site data to establish the point of contact (length of exposure to COCs) between the stressor and the mouse. The overlap of receptor home range with the site was considered sufficient for evaluation as a potential receptor and it was assumed that all of it's life is spent within the site. The period of exposure of an organism is determined by evaluating the percentage of time an organism could spend feeding within the site. This is determined by estimating the fraction of the site area within the receptor home range area. No attempt was made to discriminate between seasonal use of the site by

receptors. The usage factor for the Great Basin Pocket Mouse is shown in Appendix D and is incorporated into the dose equations.

The purpose of the exposure analysis is to integrate the spatial and temporal distributions of the ecological components and stressors to evaluate exposure.

All nonradioactive and radioactive constituents identified as of potential concern in the human health risk assessment prior to risk-based screening were considered to be of concern in the ecological risk assessment. It was assumed the receptor spends all of its life in the site. Schmidt-Nielson (1948) and Kritzman (1974) state that this species does not need free water but occasionally eats green vegetation when available.

For nonradiological constituents, concentrations estimated in mice were compared to the reported benchmark or potentially toxic concentrations. For radiological constituents, mice concentrations were converted to dose. Total dose for all radionuclides are compared to published effect levels and regulatory standards where available (Order DOE 5400.5; IAEA, 1992). The equations used to calculate radiological and hazardous chemical doses are provided in Appendix D.

2.3.2.2.2 Characterization of Ecological Effects. The relationship between the stressor and assessment and measurement endpoints is analyzed for characterization of ecological effects. The only regulatory driver for radionuclides in the environment is DOE Order 5400.5, which requires exposure limits for aquatic organisms to be less than 1 rad/day. The regulatory benchmark for terrestrial organisms has not been formally established. However, until a formal benchmark is established, hazard quotients for terrestrial ecological exposure are based on an exposure limit of 1 rad/day (NCRP 1991) for radionuclides and the NOEL dose for non-radionuclides. Because of the lack of radionuclide data for terrestrial organisms, this limit is also applied to the pocket mouse at the waste sites in the 100-HR-1 operable unit. Toxicity data for metals are also evaluated.

Ionizing radiation can impact wildlife depending upon the level of exposure. Exposure can be either acute or chronic. Depending on the concentration of exposure, acute exposures can result in organism mortality, generally characterized as the LD-50 (concentration to cause 50% mortality in some specified period of time - for mammals this is usually 30 days). Other possible effects from acute exposure are physiological and pathological changes, developmental and reproductive effects. Effects from chronic exposure include physiological, reproductive, growth, and developmental effects.

Rose (1992) reported the lower limits of lethal effects for chronic irradiation was 360 rad/year or roughly 1 rad/day for several American rodents (French et al. 1967, 1974). Semagin (1975) reported a dose of 0.008 rad/day as the lowest dose that produced an effect on the fetuses of laboratory rats irradiated during the third period of intrauterine life. It was found that body mass was reduced and brain mass increased at birth. The increase in brain mass was the result of nerve tissue and not oedema. The reported range for developmental and behavioral changes from chronic irradiation exposure was also summarized by Rose (1992). An exposure of 0.49 rad/day did not effect the growth rate of several American rodents, e.g., *Peromyscus leucopus* (Childs et al. 1966). Pocket mice (*Pergnathus formosus*) were reported unaffected at a dose of 0.96 rad/day (French et al. 1967).

In another extensive review of the affects of ionizing radiation on terrestrial organisms, the International Atomic Energy Agency (IAEA) (1992), concluded that a "dose rate of approximately 10 mGy/d (1 rad/d) represents the threshold at which slight effects of radiation become apparent in those attributes, e.g., reproduction capacity, which are of importance for the maintenance of the population.

IAEA concluded that "reproduction was the population attribute most sensitive to damage from chronic irradiation and also the attribute of greatest significance in the ecological context."

The wildlife no-observable-effect levels (NOEL) for nonradiological contaminants (DOE 1992) are given in Table 2-2. These NOELs are based upon the human reference dose with correction for uncertainty and species change from human to wildlife. The application of this value is to the amount of contaminated food stuff consumed each day. Typical transfer coefficients used in the risk assessments are provided in Appendix D.

To evaluate the toxicity of a chemical to the Great Basin pocket mouse, intake values for a given contaminant were compared with the NOEL. Toxicity information for terrestrial organisms relied on animal studies that support the Integrated Risk Information System (IRIS) (EPA 1993) and the Health Effect Assessment Summary Table (HEAST) (EPA 1992) databases, and on the U.S. Fish and Wildlife Service Studies (e.g., Eisler 1985). As a screening tool, NOEL and LOEL presented in the IRIS or when absent in the HEAST database (EPA 1992) were used for mammals. Uncertainty factors were applied to the animal toxicity data to correct for differences between species, to modify LOEL values to NOEL, and adjust data obtained through short-term studies to that which would be expected in long-term studies. LD$_{50}$ values were adjusted with uncertainty factors to obtain an estimated NOEL. The factors used to modify toxicity values included; (1) short-term (<30 days) (Newell et al 1987) effect levels were multiplied by 0.1 to estimate chronic, long-term effects, (2) LOEL were converted to NOELs by multiplying the effect concentration by 0.2 (Newell et al. 1987), (3) oral LD$_{50}$ values were converted to acute NOEL values by multiplying the effect concentration 0.2., and (4) interspecies adjustments were made by multiplying the effect concentration by 0.1 (Newell et al. 1987). For species of different phylogenetic classes (e.g., mammal to bird), 0.05 was used as the uncertainty factor. The NOELs for the indicator species were provided in specific tables in DOE (1992).

Intake of contaminants by the Great Basin pocket mouse was estimated using intake parameters obtained from either published literature or derived from EPA formulas (EPA 1988a). Intake of contaminants in vegetation was estimated using an equation adapted from EPA's Human Health Evaluation Manual (1989a).

2.3.2.3 Ecological Risk Characterization. The risk to the Great Basin Pocket Mouse was estimated by developing an environmental hazard quotient (EHQ). The EHQ was based on a comparison between identified dose benchmarks and calculated animal dose.

2.3.2.3.1 Risk Estimation. The likelihood of an adverse effect exists in the case of radiological contamination for the pocket mouse exceeding a 1 rad/day benchmark. Non-radiological contamination available toxicity data was also evaluated. The relationship between the benchmark for radionuclides or toxicity data for non-radiological chemicals was expressed as an EHQ. The EHQ is defined as the ratio of the contaminant dose to some benchmark dose/concentration, i.e., DOE Order, NOEL.

$$EHQ = \frac{\text{Organism's Dose}}{\text{Benchmark Dose}}$$

The EHQ ratio is used to assess the potential adverse effect to an individual. For example, an EHQ that approaches or exceeds unity would strongly indicate an adverse effect to an individual. For chemicals such as arsenic, the NOEL was used to assess risk. The EHQ at or above 1 would indicate a potential measurable risk.

2.3.2.3.2 Risk Description. This section summaries risk assessment for each waste site along with risk drivers.

The ecological significance of the QRA is limited since the purpose of the QRA is to assess risk at a waste site. A summary of the risk assessment, for those waste sites with known contaminants and concentrations, is provided. The risk-driving contaminants are described in the summary. Any further interpretation of results for a waste site goes beyond the original purpose of the QRA.

THIS PAGE INTENTIONALLY
LEFT BLANK
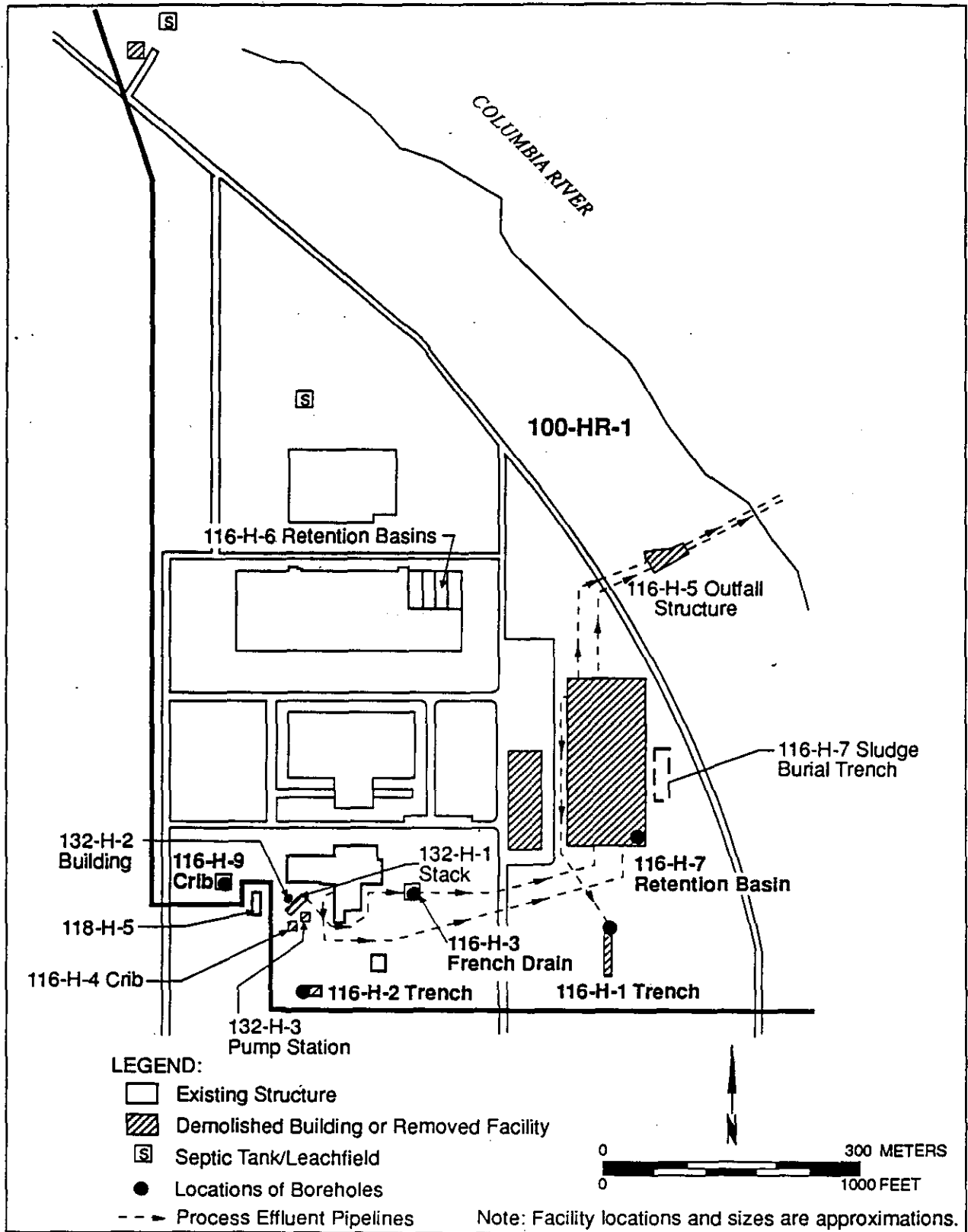
Figure 2-1. Limited Field Investigation Borehole Sampling Locations for 116-H-1, 116-H-2, 116-H-3, 116-H-7 and 116-H-9 Waste Sites.

THIS PAGE INTENTIONALLY
LEFT BLANK

Phase 1 of Contaminant Identification Process: Screening Against Background

Substance in a Specific Environmental Medium

↓

Validated Sampling Data

↓

Compare to Hanford Site Background Control Distributions

Maximum-detected concentration is outside tolerance interval of background control distribution?

Hanford Site background control distributions are not available

Yes → Substance is a contaminant

No → Substance is not a contaminant

Substance is essentially non-toxic under typical environmental exposure scenarios (e.g., Al, Ca, Fe, Mg, K, Na)

Yes

No → Conduct preliminary risk-based screening (Phase 2)

Maximum-detected concentration poses a potential ecotoxicological hazard? (Based on best professional judgement)

Yes → Substance is a contaminant of potential concern for environmental evaluation

No → Eliminate substance from further consideration

923 E007/44824/7-19-93

Figure 2-2. Overview of Contaminant Identification Process: Phase 1.

THIS PAGE INTENTIONALLY
LEFT BLANK

II°
Carnivores

| Loggerhead Shrikes | → | Coyotes |

Swainson's Hawks

Sage Thrashers

Burrowing Owls

I°
Carnivores

Red-Tailed Hawks

Ferru-ginous Hawks

Snakes

Meadowlarks, Sage Sparrows Curlews

Predatory Insects/ Arthropods

Badgers

Herbivores

Small Mammals

Horned Larks

Herbivorous Insects

Deer

Lagomorphs

Primary Producers

Seeds

Vegetation

923 E007/44817/3-19-93
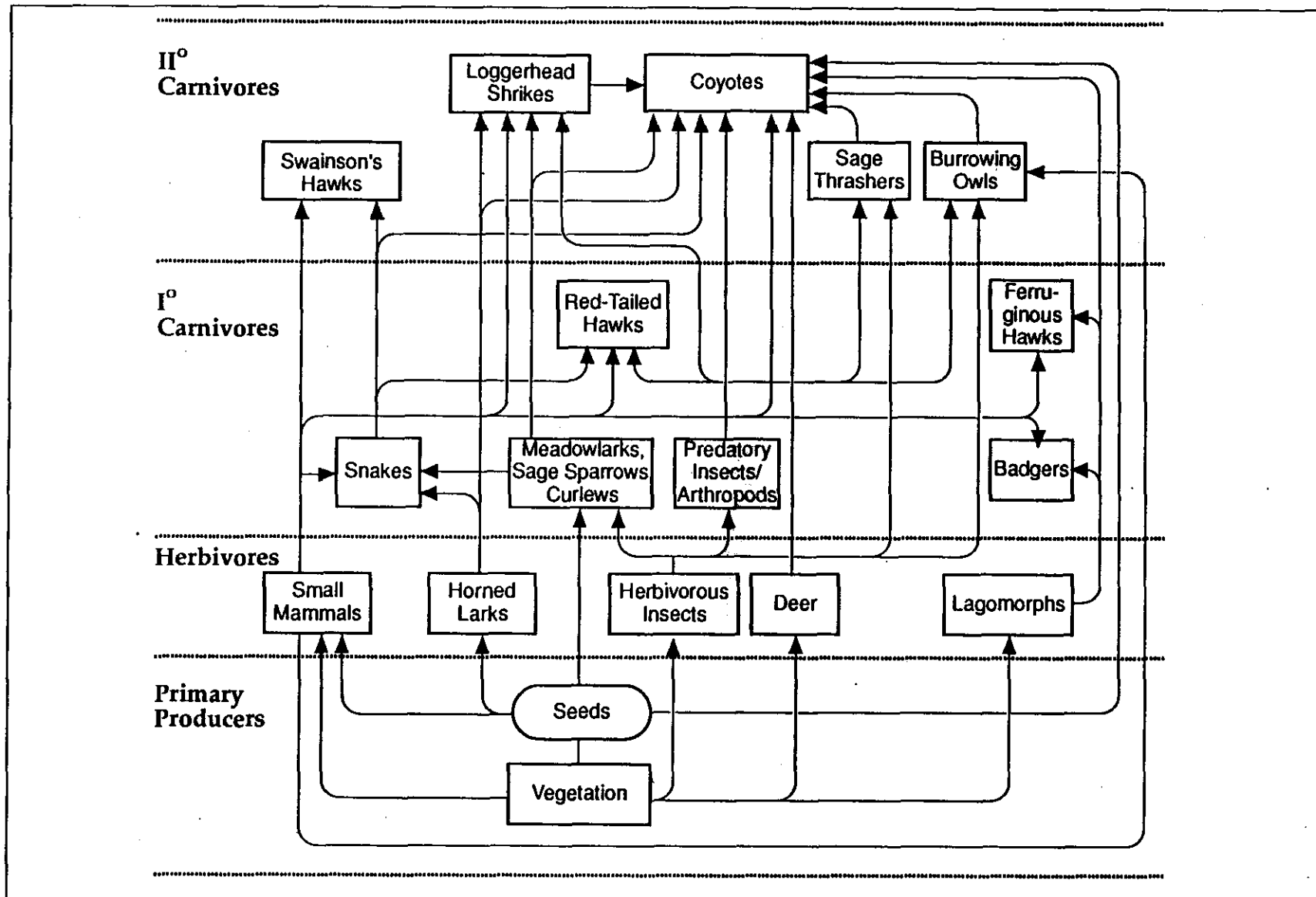
Figure 2-3. Conceptual Ecological Model.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 2-1. The Hanford Site Wide Background Summary Statistics and Upper Threshold Limits (UTLs) for Inorganic Analytes. (Sheet 1 of 2)

Analyte	95% Distribution[a] (mg/kg)	95% UTL[b] (mg/kg)
Aluminum	13,800	15,600
Antimony	NR	15.7[c]
Arsenic	7.59	8.92
Barium	153	171
Beryllium	1.62	1.77
Cadmium	NR	0.66[c]
Calcium	20,410	23,920
Chromium	23.4	27.9
Cobalt	17.9	19.6
Copper	25.3	28.2
Iron	36,000	39,160
Lead	12.46	14.75
Magnesium	7,970	8,760
Manganese	562	612
Mercury	0.614	1.25
Molybdenum	NR	1.4[c]
Nickel	22.4	25.3
Potassium	2,660	3,120
Selenium	NR	5[c]
Silver	1.4	2.7
Sodium	963	1,290
Thallium	NR	3.7[c]
Titanium	3,020	3,570
Vanadium	98.2	111
Zinc	73.3	79
Zirconium	47.3	57.3

Table 2-1. The Hanford Site Wide Background Summary Statistics and
Upper Threshold Limits (UTLs) for Inorganic Analytes. (Sheet 2 of 2)

Analyte	95% Distribution[a] (mg/kg)	95% UTL[b] (mg/kg)
Ammonia	15.3	28.2
Alkalinity	13,400	23,300
Chloride	303	763
Fluoride	6.4	12
Lithium	35	37.1
Nitrate	96.4	199
Nitrite	NR	21[c]
Ortho-phosphate	3.7	16
Silicon	108	192
Sulfate	580	1,320

Source: DOE-RL 1993b
Notes:
NR = Not reported
[a] 95th percentile of the data for a lognormal distribution
[b] 95% confidence limit of the 95th percentile of the data distribution
[c] Limit of detection

Table 2-2. Estimated Wildlife NOEL.

Chemical	Adjusted Wildlife NOEL (mg/kg-day)
Arsenic	0.00008
Barium	0.02
Beryllium	0.05
Chromium	0.20
Manganese	0.01
Lead	0.000069
Vanadium	0.07
Zinc	0.20
Benzo(a)pyrene	NA
NA - Not Available. Source: DOE 1992	

THIS PAGE INTENTIONALLY LEFT BLANK

Table 2-3. Threatened, Endangered, and Candidate Birds of the Hanford Site
That May Occur in the Vicinity of the 100-H Area.

Common Name	Latin Name	Federal Status	State Status
bald eagle[a]	*Haliaeetus leucocephalus*	threatened	threatened
peregrine falcon[b]	*Falco peregrinus*	endangered	endangered
American white pelican[a]	*Pelecanus erythrorhynchos*	-	endangered
sandhill crane[a]	*Grus canadensis*	-	endangered
ferruginous hawk[a]	*Buteo regalis*	candidate	threatened
loggerhead shrike[a]	*Lanius ludovicianus*	candidate	candidate
sage grouse[b,c]	*Centrocercus urophasianus*	candidate	candidate
common loon[a]	*Gavia immer*	-	candidate
northern goshawk[c]	*Accipiter gentilis*	-	candidate
Swainson's hawk[a]	*Buteo swainsoni*	candidate-3	candidate
golden eagle[a]	*Aquila chrysaetos*	-	candidate
flammulated owl[c]	*Otus flammeolus*	-	candidate
burrowing owl[c]	*Athene cunicularia*	-	candidate
sage thrasher[c]	*Oreoscoptes montanus*	-	candidate
sage sparrow[a]	*Amphispiza belli*	-	candidate
long-billed curlew[a]	*Numenius americanus*	candidate-3	-

[a] Observed during 100 Area surveys (Sackschewsky and Landeen 1992).
[b] Accidental occurrence, not likely to be found on the area.
[c] 100 Area contains suitable habitat for this species.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 2-4. Mammals of the Hanford Site Associated with the Riparian
Zone of the Columbia River. (Sheet 1 of 2).

Family	Common Name	Latin Name	Abundance	Habitat Association
Soricidae	vagrant shrew	*Sorex vagrans*	uncommon	riparian
Vespertilionidae	pallid bat	*Antrozous pallidus*	common - summer	buildings
	little brown myotis	*Myotis lucifugus*	common - summer	buildings
	Yuma myotis	*Myotis yumanensis*	common - summer	buildings
	western big-eared bat	*Plecotis townsendii*	unknown	buildings
Leporidae	black-tailed jackrabbit[a]	*Lepus californicus*	common	shrublands/grasslands
	Nuttall's cottontail[a]	*Sylvilagus nuttallii*	common	buildings
Sciuridae	Townsend ground squirrel	*Spermophilus townsendii*	common	shrublands/grasslands
Geomyidae	northern pocket gopher[a]	[a]*Thomomys talpoides*	common	shrublands/grasslands
Heteromyidae	Great Basin pocket mouse[a]	*Perognathus parvus*	common	shrublands/grasslands
Castoridae	beaver[a]	*Castor canadensis*	common	river/riparian
Cricetidae	western harvest mouse	*Reithrodontomys megalotis*	rare	shrublands/riparian
	deer mouse	*Peromyscus maniculatus*	common	entire site
	northern grasshopper mouse	*Onychomys leucogaster*	rare	riparian
	bushy-tailed wood rat[a]	*Neotoma cinerea*	common	entire site
	montane vole	*Microtus montanus*	rare	riparian
	sagebrush vole	*Lagurus curtatus*	rare	shrublands
	muskrat[a]	*Ondatra zibethica*	rare	river/riparian
Muridae	Norway rat	*Rattus norvegicus*	common	buildings
	house mouse	*Mus musculus*	common	buildings/riparian
Erethizontidae	porcupine[a]	*Erithizon dorsatum*	uncommon	entire site
Canidae	coyote[a]	*Canis latrans*	uncommon	entire site
Procyonidae	racoon	*Procyon lotor*	uncommon	riparian

Table 2-4. Mammals of the Hanford Site Associated with the Riparian
Zone of the Columbia River. (Sheet 2 of 2).

Family	Common Name	Latin Name	Abundance	Habitat Association
Mustelidae	mink	*Mustela vison*	rare	river/riparian
	long-tailed weasel	*Mustela frenata*	uncommon	riparian
	short-tailed weasel	*Mustela erminea*	rare	riparian
	otter	*Lutra canadensis*	rare	river/riparian
	badger[a]	*Taxidea tasus*	uncommon	entire site
	striped skunk	*Mephitis mephitis*	uncommon	riparian
Felidae	bobcat	*Lynx rufus*	rare	entire site
Cervidae	mule deer[a]	*Odocoileus hemionus*	common	entire site
	white-tailed deer	*Odocoileus virginianus*	rare	riparian

[a]Mammals observed by Sackschewsky and Landeen (1992).

Table 2-5. General Soil-to-Plant Transfer Coefficients Used for Constituents of Potential Concern.

Contaminant	Plant/Soil Transfer Coefficient	Reference
Americium 241	1.0E-02	Coughtrey et al. 1985
Carbon 14	5.5	Whicker and Schultz 1982
Cobalt 60	0.5	Coughtrey et al. 1985
Cesium 134	2.5E-01	Coughtrey et al. 1985
Cesium 137	0.6	Miller et al. 1977
Europium 152	0.001	Coughtrey et al. 1985
Europium 154	0.001	Coughtrey et al. 1985
Europium 155	0.001	Coughtrey et al. 1985
Tritium	4.8	Whicker and Schultz 1982
Nickel 63	0.1	Coughtrey et al. 1985
Plutonium 238	7.0E-02	Coughtrey et al. 1985
Plutonium 239	7.0E-02	Coughtrey et al. 1985
Radium 226	0.1	Coughtrey et al. 1983 and 1985
Strontium 90	19	Rouston and Cataldo 1978
Thorium 228	1.0E-04	Whicker and Schultz 1982
Uranium 234	1	Whicker and Schultz 1982
Uranium 235	1	Whicker and Schultz 1982
Uranium 238	1	Whicker and Schultz 1982
Antimony	0.1	Coughtrey et al. 1983 and 1985
Barium	0.15	DOE 1992
Benzo(a)pyrene	0.013	DOE 1992
Chromium	0.0075	DOE 1992
Chrysene	0.022	DOE 1992
Lead	0.045	DOE 1992
Mercury	0.9	DOE 1992
Pentachlorophenol	0.046	DOE 1992
Zinc	1.5	DOE 1992

**THIS PAGE INTENTIONALLY
LEFT BLANK**

3.0 HIGH-PRIORITY WASTE SITE QUALITATIVE RISK ASSESSMENT

Historical information used in this section was obtained from the 100-HR-1 operable unit work plan (DOE-RL 1992b) unless otherwise referenced. The concentrations and inventories of selected radionuclides presented in this section may not be inclusive of all potential radionuclides in the samples because of the limited data sets reported in the radiological characterization of the 100-HR-1 operable unit performed by Dorian and Richards (1978). In addition, limited data are available from historical information for the characterization of non-radioactive inorganic and organic constituents that may be present in the waste sites.

3.1 116-H-1 TRENCH

3.1.1 Historical Data for the 116-H-1 Trench

The 116-H-1 trench is located directly south of the 116-H-7 retention basin, in the southeast corner of the 100-HR-1 operable unit, and measures 60 m x 7.5 m x 4.6 m (200 x 25 x 15 ft) deep (see Figure 1-3). From 1952 to 1965, the trench served as an emergency disposal crib for process effluents contaminated by fuel element ruptures. After 1954, the trench was inactivated and in 1965 sludge from the 116-H-7 retention basin was disposed of in this unit. The unit was originally covered to grade with 1.9 m (5 ft) of soil. A radiological inventory (Dorian and Richards 1978) has identified tritium, cobalt-60, strontium-90, cesium-134, cesium-137, europium-152, europium-154, europium-155, uranium, plutonium-238, plutonium-239, and plutonium-240. The isotopes of uranium were not specified. Approximately 90 kg (200 lb) of sodium dichromate were disposed of in the 116-H-1 trench. Historical data are presented in Appendix A.

3.1.2 LFI Data for the 116-H-1 Trench

The LFI data collected for the 116-H-1 trench consists of one borehole drilled into the trench with six soil samples collected beginning at 3 m (10 ft) below the ground surface to a depth of 7.3 m (24 ft) (see Figure 2-1). Borehole logs indicate approximately 14 ft of sandy gravel fill currently overlies the trench. This is an additional 9 ft of fill than was originally present. The samples were analyzed for radionuclides, PCBs, pesticides, TAL, and TCL analytes. In addition, five split tubes and five archive samples were collected from 0 to 7.6 m (0 - 25 ft) depth. All sample depths indicated are the top of the sampling interval. The borehole logs for the LFI data for this site indicate that radiation is less than detectable at ground surface to the bottom of the fill at approximately 4.3 m (14 ft), then detectable between 4.3 and 5.8 m (14 and 19 ft).

Laboratory results identified radionuclides, inorganic and organic compounds. All sample data are evaluated for use in the preliminary screening process. Alpha spectrometry data (americium-241, carbon-14, uranium-235 and plutonium-239/240) are rejected by validation due to missing documentation on calibration information. These data are evaluated in the preliminary screening.

3.1.3 Data Summary for the 116-H-1 Trench

The maximum concentrations of the historical radionuclide data reported at or above 4.6 m (15 ft) decayed to 1992 and the LFI data are summarized in Table 3-1a. The data have been compared and the maximum concentration from either historical data, decayed to 1992, or LFI data for any detected parameter is used in the QRA for current exposures. The maximum concentration is also decayed to 2018 for evaluation of future exposures.

The historical data are compared to the LFI data with the following items noted:

- Historical or LFI data are either not reported (the laboratory did not analyze for a particular compound), were not reported above the detection limits, or were not reported above 4.6 m (15 ft) for carbon-14, sodium-22, thorium-232 or uranium-235. These parameters are, therefore, not evaluated in the QRA for this waste site.

- Cesium-134, europium-155, plutonium-238 and tritium are reported as detects in the historical data, but are reported below detection or not analyzed for in the LFI data. The historical data are used in the QRA.

- Americium-241, potassium-40, radium-226, technetium-99, and thorium-228 are either not reported or not detected in the historical data. The LFI data are used in the QRA.

- The inorganic and organic LFI data are evaluated in the QRA because no historical data exist for these parameters. The organic and inorganic parameters which were not reported at or above 4.6 m (15 ft) in the LFI are not evaluated in the QRA. However, the impact to groundwater for the contaminants below 4.6 m (15 ft) is evaluated in Section 3.1.6.

- Aluminum, calcium, iron, magnesium, potassium and sodium are eliminated from consideration in the QRA based on evaluation as recommended in HSBRAM (DOE-RL 1993a).

- Lead, benzo(a)anthracene, benzo(b), and (k)fluoranthene, chrysene, dibenzofuran, indeno(1,2,3-CD)pyrene, and phenanthrene lack toxicity data for risk calculation. Lead concentrations do not exceed the EPA soil cleanup guidelines of 500-1,000 mg/kg.

3.1.4 Qualitative Risk Assessment for the 116-H-1 Disposal Trench - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the contaminants of potential concern, the exposure and toxicity assessment and the risk characterization for the 116-H-1 trench.

3.1.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of inorganic parameters presented in Table 3-1a are compared to Hanford Site background concentrations, as discussed in Section 2.2. Barium, cobalt, chromium, copper, manganese, nickel, vanadium and zinc concentrations are lower than the background concentrations and are eliminated from further evaluation in the QRA. The remaining inorganic, all organic, and radionuclide parameters that have been identified in Table 3-1a are carried through the preliminary risk-based screening.

Radionuclides that exceed screening criteria are indicated by shading in Table 3-1b while inorganic and organic constituents that exceed screening criteria are indicated by shading on Table 3-1c. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the 116-H-1 trench and are further evaluated in the QRA for both human health and environmental receptors.

Due to the large quantities of sodium dichromate released at this and other waste sites in the 100-HR-1 operable unit it might be expected that chromium concentrations be significantly elevated at these waste sites. The fact that chromium is not universally detected is probably due to the fact that sodium dichromate dissociates in water to release the free chromium anion. The mobility of this species in the subsurface environment and the large volumes of water released at many waste sites in 100-HR-1 is a likely reason that chromium was infrequently detected in the sampling programs.

3.1.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Intakes are provided for both noncarcinogenic and carcinogenic effects. Specific intakes are not presented if there are no slope factors (SFs) or chronic reference doses (RfDs) available to evaluate a contaminant of potential concern.

3.1.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for both noncarcinogenic and carcinogenic substances carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.1.4.4 Risk Characterization. The risk characterization is based upon information from the exposure assessment and toxicity assessment. It forms the basis for characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-1 trench. The risk characterization is conducted as described in Section 2.3. Calculated ICRs, HQs, and HIs are compared to an ICR of 1E-06 and an HI of 1 for the 116-H-1 trench. All ICRs exceeding 1E-06 and all HQs exceeding unity, are highlighted in Tables 3-1d, 3-1e, and 3-1f.

3.1.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying contaminants and concentrations for risk assessment. The LFI data for the 116-H-1 trench site are of known quality, are analyzed using EPA

methods and are validated prior to use. However, the validated data have been reviewed and some rejected or estimated data have been included in the QRA. For instance, J (estimated values) are used and R (rejected values) are used if the reason for rejection is missing calibration sheets. None of the LFI radionuclide data used for the 116-H-1 trench QRA were rejected due to missing calibration sheets.

The historical data and LFI data, as presented in Table 3-1a, indicate differences. The LFI soil sampling data identifies contaminants that are greater than 3 m (10 ft) or more below ground surface (BGS). Borehole logs documenting drilling activities indicate no detectable radiation above background in the top 14 ft of the borehole. Contrary to this, the historical data reports higher radionuclide concentrations, decayed to 1992, approximately 0.6 m (2 ft) BGS where the LFI survey indicated no radiation above background. This is probably due to differing depths of fill material at present than existed when the historical data were collected.

The contaminants and concentrations identified in the LFI data are not necessarily representative of the upper 4.6 m (15 ft) of soil. The concentrations of the contaminants identified may be under or overestimated since only one borehole was drilled for sampling. "Hot spots" may be present in the 116-H-1 trench that were not sampled. The possibility exists that contaminants may be present other than those identified.

The risks estimated in this QRA are based on the maximum concentrations detected in the LFI and historical data above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740 (6)(c)]. This assumption may overestimate current risks because institutional control prevents intrusion at the waste site.

Historical data for chemical (non-radiological) constituents are not available, and as such, no comparisons between the two are made. The LFI data have been used for all inorganic and organic parameters in the QRA.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, ingestion, and inhalation. The 116-H-1 trench is reported to be filled with gravel and exposure to the contaminants that are currently buried to a depth of 3 to 4.6 m (10 to 15 ft) BGS would require extensive excavation. The risks of exposure, should contact with the contamination be reached, would be as estimated for this QRA. A primary uncertainty, however, is what contaminants may be present in the overlying gravel which exists today. Based on LFI survey data, radionuclides are not present above field detection levels until 4.3 m (14 ft). However, the presence of inorganics or organics in the overlying gravel is unknown.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate for the current conditions at the site.

3.1.4.6 Qualitative Discussion of the Threat Posed by the 116-H-1 Trench. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Tables 3-1d and 3-1f, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is >1E-02 and is mainly attributable to cesium-137, cobalt-60, europium-152, and europium-154 via the external pathway.

- For the occasional-use scenario, the estimated risk is 5E-04 and is mainly attributable to cesium-137 and europium-152 via the external pathway.

Non-radioactive contaminants:

- For the frequent- and occasional-use scenarios, the estimated risks are 1E-04 (HI = 2) and 2E-06 (HI =0.03), respectively, mainly attributable to arsenic via the soil ingestion pathway.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-1e, is >1E-02 and is mainly attributable to cesium-137 and europium-152 via the external pathway.

The total estimated risks for the 116-H-1 waste site are based primarily on the historical data collected from the site. The degree of confidence is high for the types of contaminants present at the site. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the contaminant concentrations and the estimated risks is medium, because most of the risk-producing data used are historical data. The risks are based on scenarios that represent high-frequency use of the waste site and low-frequency use of the site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimate at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk for external exposure may be an overestimate at this waste site.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. At 116-H-1, the risk-driving contaminants are found primarily in the upper 6 ft of soil. Therefore, the external exposure risk can be calculated to exceed 1E-06 under the current occasional-use scenario. This conclusion is not supported by radiological survey data, which indicates surface radiation levels are not elevated above background. Additional fill may have been added since the historical data were collected, which could account for this discrepancy.

Based on the QRA, the threat posed by radionuclides in 1992 at 116-H-1 would be high under the frequent-use scenario and medium under the occasional-use scenario. The threat posed by radionuclides under the frequent-use scenario in 2018 would be high. The

threat posed by radionuclides under the frequent-use scenario in 2018 would be high. The threat posed by non-radioactive contaminants would be medium under the frequent-use scenario and low under the occasional-use scenario.

3.1.5 Qualitative Risk Assessment for the 116-H-1 Trench - Ecological Evaluation

The total dose to the Great Basin Pocket Mouse from radionuclides present in the soil of the 116-H-1 trench is shown in Tables 3-1g and 3-1h. The total dose from the 0-6 ft soil interval is 1.5 rad/day of which over 99% is attributable to strontium-90. Arsenic and benzo(a)pyrene were also measured in the 6-15 ft soil interval. The daily dose from arsenic and benzo(a)pyrene is 0.48 and 0.0034 mg/kg/day.

The radiological dose for waste site 116-H-1 is above the 1 rad/day benchmark and arsenic exceeds the wildlife NOEL. Benzo(a)pyrene is a cancer producing chemical and no NOEL can be derived.

3.2 THE 116-H-2 TRENCH

3.2.1 Historical Data for the 116-H-2 Trench

The 116-H-2 trench is situated outside the H reactor building security fence in the far southwestern corner of the 100-HR-1 operable unit (see Figure 1-3). The trench measures 82.5 m x 30 m x 1.8 m deep (275 x 100 x 6 ft deep). Decontamination wastes generated during reactor shutdown and standby periods were disposed of in this unit. Wastes were collected in the 132-H-3 pump station sumps and pumped to the 116-H-2 trench. The trench was utilized from 1953, and after its retirement in 1965, was covered to grade with soil. Dorian and Richards (1978) detected tritium, cobalt-60, strontium-90, cesium-134, cesium-137, europium-152, europium-154, europium-155, uranium-235, uranium-238, plutonium-239 and plutonium-240. Approximately 600 kg (1,300 lb) of sodium dichromate were disposed of in the 116-H-2 trench. Historical data are provided in Appendix A.

3.2.2 LFI Data for the 116-H-2 Trench

The LFI data collected for the 116-H-2 trench consist of one borehole drilled into the trench to a depth of 5.2 m (17 ft) with two samples collected beginning at 3 m (10 ft) below ground surface to a depth of 4.6 m (15 ft) (see Figure 2-1). Samples were analyzed for radionuclides, PCBs, pesticides, TAL and TCL analytes. Three soil samples [1.5, 3.0 and 4.5 m (5, 10 and 15 ft)] were archived. All sample depths indicated are the top depth of the sampling range. The borehole logs for the LFI data for this site indicate that radiation is less than detectable (using field instruments) throughout the borehole.

Laboratory results identified radionuclides and inorganic constituents. All sample data are evaluated for use in the preliminary screening process.

3.2.3 Data Summary for the 116-H-2 Trench

The maximum concentrations of the historical radionuclide data reported at or above 4.6 m (15 ft), decayed to 1992, and the LFI data are summarized in Table 3-2a. The data have been compared and the maximum concentration from either historical data, decayed to 1992, or LFI data for any detected parameter is used in the QRA for current exposures. The maximum concentration is also decayed to 2018 for evaluation of future exposures.

The historical data are compared to the LFI data with the following items noted:

- Except for uranium, no radionuclides were analyzed in both historical and LFI data.

- Historical data are either not reported (the laboratory did not analyze for a particular compound), or were not reported above the detection limits, for potassium-40, radium-226, thorium-228, and thorium-232. The LFI data are evaluated in the QRA for this waste site.

- Cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, plutonium-239/240, strontium-90 and tritium are reported as detects in the historical data, but are reported below detection or not analyzed for in the LFI data. The historical data are used in the QRA.

- Aluminum, calcium, iron, magnesium, potassium and sodium are eliminated from consideration in the QRA based on evaluation as recommended in HSBRAM (DOE-RL 1993a).

3.2.4 Qualitative Risk Assessment for the 116-H-2 Trench - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the contaminants of potential concern, the exposure and toxicity assessment and the risk characterization for the 116-H-2 trench.

3.2.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of inorganic parameters presented in Table 3-2a are compared to Hanford Site background concentrations, as discussed in Section 2.2. Barium, cobalt, chromium, copper, lead, manganese, nickel, vanadium and zinc concentrations are lower than the background concentrations and are eliminated from further evaluation in the QRA. Radionuclide parameters that have been identified in Table 3-2a are carried through the preliminary risk-based screening.

Radionuclides that exceed screening criteria are indicated by shading in Table 3-2b. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the 116-H-2 trench and are further evaluated in the QRA for both human health and environmental receptors.

Due to the large quantities of sodium dichromate released at this and other waste sites in the 100-HR-1 operable unit it might be expected that chromium concentrations be significantly elevated at these waste sites. The fact that chromium is not universally detected is probably due to the fact that sodium dichromate dissociates in water to release the free chromium anion. The mobility of

this species in the subsurface environment and the large volumes of water released at many waste sites in 100-HR-1 is a likely reason that chromium was infrequently detected in the sampling programs.

3.2.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Specific intakes are not presented if there are no slope factors (SFs) available to evaluate a contaminant of potential concern.

3.2.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for both noncarcinogenic and carcinogenic substances carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.2.4.4 Risk Characterization. The risk characterization is based upon information from the exposure assessment and toxicity assessment. It forms the basis for characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-2 trench. The risk characterization is conducted as described in Section 2.3. Calculated ICRs are compared to an ICR of 1E-06 for the 116-H-2 trench. All ICRs exceeding 1E-06 are highlighted in Tables 3-2c and 3-2d.

3.2.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying contaminants and concentrations for risk assessment. The LFI data for the 116-H-2 trench site are of known quality, are analyzed using EPA methods and are validated prior to use. However, the validated data have been reviewed and some rejected or estimated data have been included in the QRA. For instance, J (estimated values) are used and R (rejected values) are used if the reason for rejection is missing calibration sheets. None of the LFI radionuclide data used for the 116-H-2 trench QRA were rejected due to missing calibration sheets.

The historical data and LFI data, as presented in Table 3-2a, indicate differences. The historical soil sampling data identifies contaminants that are from 0.3 to 3 m (1 to 10 ft) below ground surface (BGS). Borehole logs documenting drilling activities in 1992 indicate no detectable radiation above background throughout the borehole. The LFI data reports detectable radionuclide concentrations, at 3 and 4.6 m (10 and 15 ft) BGS where the LFI survey indicated no radiation above background. These discrepancies may be due to differing depths of fill material at present than existed when the historical data was collected, and to interference by background radiation during the borehole surveys.

The contaminants and concentrations identified in the LFI data are not necessarily representative of the upper 4.6 m (15 ft) of soil. The concentrations of the contaminants identified may be under or overestimated since only one borehole was drilled for sampling. "Hot spots" may be present in the 116-H-2 trench that were not sampled. The possibility exists that contaminants may be present other than those identified.

The risks estimated in this QRA are based on the maximum concentrations detected in the LFI and historical data set above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740 (6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion, and inhalation. At the 116-H-2 trench, contaminants are reported in the historical data at 0.3 m (1 ft) BGS. It is possible that additional fill has been added since the historical data were collected, in which case risk-driving contaminants would occur today at greater depth. The risks of exposure, should contact with the contamination be reached, would be as estimated for this QRA. A second uncertainty is what contaminants may be present in the overlying gravel which exists today. Based on LFI survey data, radionuclides are not present above field detection levels to a depth of 5.2 m (17 ft). However, the presence of inorganics or organics in the overlying gravel is unknown.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate for the current conditions at the site.

3.2.4.6 Qualitative Discussion of the Threat Posed by the 116-H-2 Trench. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Table 3-2c, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is 5E-03 and is mainly attributable to cesium-137, and europium-152 via the external pathway.

- For the occasional-use scenario, the estimated risk is 3E-05 and is mainly attributable to cesium-137 and europium-152 via the external pathway.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-2d, is 2E-03 and is mainly attributable to cesium-137 via the external pathway.

The total estimated risks for the 116-H-2 waste site are based primarily on the historical data collected from the site. Because most of the risk-producing data available are historical data, the degree of confidence is medium for the types of contaminants present at the site even though LFI data exists. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the contaminant concentrations and the estimated risks is also medium. The risks are based on scenarios that represent high frequency use of the waste site and low frequency use of the site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimate at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk for external exposure may be an overestimate at this waste site.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. At 116-H-2, the risk-driving contaminants are found primarily in the upper 6 ft of soil. Therefore, the external exposure risk can be calculated to exceed 1E-06 under the current occasional-use scenario. This conclusion is supported by radiological survey data which indicates surface radiation levels elevated above background.

Based on the QRA, the threat posed by radionuclides in 1992 at 116-H-2 would be medium under the frequent-use scenario and low under the occasional-use scenario. The threat posed by radionuclides under the frequent-use scenario in 2018 would be medium.

3.2.5 Qualitative Risk Assessment for the 116-H-2 Trench - Ecological Evaluation

The total dose to the Great Basin Pocket Mouse from radionuclides present in soil of the 116-H-2 trench is shown in Tables 3-2e and 3-2f. The total dose for the 0-6 and 0-15 ft. soil intervals is 4.1 rad/day all of which is attributable to strontium-90. Non-radiological constituents are not identified as being present for this waste site.

The radiological dose is above the 1 rad/day benchmark for the Great Basin Pocket Mouse.

3.3 THE 116-H-3 FRENCH DRAIN

3.3.1 Historical Data for the 116-H-3 French Drain

The 116-H-3 french drain is situated within the H reactor building security fence directly east of the H reactor (see Figure 1-3). The drain is 0.9 m (3 ft) in diameter and 4.6 m (15 ft) deep and is constructed of vitreous tile conduit. Decontamination wastes generated during decontamination of fuel element spacers were disposed of in this unit. The trench was utilized from 1950 to 1965, and is presently covered to grade with soil. Dorian and Richards (1978) detected tritium, cobalt-60, strontium-90, cesium-137, europium-152, europium-154, europium-155, and plutonium-239. Approximately 2,000 kg (4,400 lb) of sodium dichromate were disposed of in the 116-H-3 drain. Historical data are provided in Appendix A.

3.3.2 LFI Data for the 116-H-3 French Drain

The LFI data collected for the 116-H-3 french drain consist of one borehole drilled into the drain to a depth of 7 m (22 ft) with two split soil samples collected beginning at 3 m (10 ft) below ground surface to a depth of 7 m (22 ft) (see Figure 2-1). Samples were analyzed for radionuclides, PCBs, pesticides, TAL and TCL analytes. Four soil samples [1.5 to 7 m (5 to 20 ft)] were archived. All sample depths indicated are the top depth of the sampling range. The

borehole logs for the LFI data for this site indicate that radiation is less than detectable (using field instruments) throughout the borehole.

Laboratory results identified radionuclides, inorganic and organic constituents. All sample data are evaluated for use in the preliminary screening process.

3.3.3 Data Summary for the 116-H-3 French Drain

The maximum concentrations of the historical radionuclide data reported at or above 4.6 m (15 ft), decayed to 1992, and the LFI data are summarized in Table 3-3a. The data have been compared and the maximum concentration from either historical data, decayed to 1992 or LFI data for any detected parameter is used in the QRA for current exposures. The maximum concentration is also decayed to 2018 for evaluation of future exposures.

The historical data are compared to the LFI data with the following items noted:

- Historical or LFI data are either not reported (the laboratory did not analyze for a particular compound), were not reported above the detection limits, or were not reported above 4.6 m (15 ft) for radium-226, and uranium 233/234. The LFI data are evaluated in the QRA for this waste site.

- Cesium-137, europium-154, europium-155, plutonium-239/240, strontium-90 and tritium are reported as detects in the historical data, but are reported below detection or not analyzed for in the LFI data. The historical data are used in the QRA.

- The organic and inorganic parameters which were not reported at or above 4.6 m (15 ft) in the LFI are not evaluated in the QRA.

- Aluminum, calcium, iron, magnesium, potassium and sodium are eliminated from consideration in the QRA based on evaluation as recommended in HSBRAM (DOE-RL 1993a).

3.3.4 Qualitative Risk Assessment for the 116-H-3 French Drain - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the contaminants of potential concern, the exposure and toxicity assessment and the risk characterization for the 116-H-3 french drain.

3.3.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of inorganic parameters presented in Table 3-3a are compared to Hanford Site background concentrations, as discussed in Section 2.2. Barium, cobalt, chromium, copper, manganese, nickel, vanadium and zinc concentrations are lower than the background concentrations and are eliminated from further evaluation in the QRA. Radionuclide parameters that have been identified in Table 3-3a are carried through the preliminary risk-based screening.

Radionuclides that exceed screening criteria are indicated by shading in Table 3-3b. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the 116-H-3 french drain and are further evaluated in the QRA for both human health and environmental receptors.

Due to the large quantities of sodium dichromate released at this and other waste sites in the 100-HR-1 operable unit it might be expected that chromium concentrations be significantly elevated at these waste sites. The fact that chromium is not universally detected is probably due to the fact that sodium dichromate dissociates in water to release the free chromium anion. The mobility of this species in the subsurface environment and the large volumes of water released at many waste sites in 100-HR-1 is a likely reason that chromium was infrequently detected in the sampling programs.

3.3.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Specific intakes are not presented if there are no slope factors (SFs) available to evaluate a contaminant of potential concern.

3.3.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for both noncarcinogenic and carcinogenic substances carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.3.4.4 Risk Characterization. The risk characterization is based upon information from the exposure assessment and toxicity assessment. It forms the basis for characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-3 french drain. The risk characterization is conducted as described in Section 2.3. Calculated ICRs are compared to an ICR of 1E-06 for the 116-H-3 french drain. All ICRs exceeding 1E-06 are highlighted in Tables 3-3c and 3-3d.

3.3.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying contaminants and concentrations for risk assessment. The LFI data for the 116-H-3 french drain site are of known quality, are analyzed using EPA methods and are validated prior to use. However, the validated data have been reviewed and some rejected or estimated data have been included in the QRA. For instance, J (estimated values) are used and R (rejected values) are used if the reason for rejection is missing calibration sheets. None of the LFI radionuclide data used for the 116-H-3 french drain QRA were rejected due to missing calibration sheets.

The historical data and LFI data, as presented in Table 3-3a, indicate differences. The historical soil sampling data identifies contaminants that are at 1.2 and 4.6 (4 and 15 ft) below ground surface (BGS). Borehole logs documenting drilling activities in 1992 indicate no detectable radiation above background throughout the borehole. The LFI data reports detectable radionuclide concentrations, at 4.6 and 6 m (15 and 20 ft) BGS where the LFI survey indicated no radiation above background. These discrepancies may be due to differing depths of fill material at present

than existed when the historical data was collected, and to interference by background radiation during the borehole surveys.

The contaminants and concentrations identified in the LFI data are not necessarily representative of the upper 4.6 m (15 ft) of soil. The concentrations of the contaminants identified may be under or overestimated since only one borehole was drilled for sampling. "Hot spots" may be present in the 116-H-3 french drain that were not sampled. The possibility exists that contaminants may be present other than those identified.

The risks estimated in this QRA are based on the maximum concentrations detected in the LFI and historical data above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740 (6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion, and inhalation. At the 116-H-3 french drain contaminants are reported in the historical data at 1.2 m (4 ft) BGS. It is possible that additional fill has been added since the historical data were collected, in which case risk-driving contaminants detected at 1.2 m (4 ft) would currently occur at greater depth. The risks of exposure, should contact with the contamination be reached, would be as estimated for this QRA. A second uncertainty is what contaminants may be present in the overlying gravel which exists today. Based on LFI survey data, radionuclides are not currently present above field detection levels in the top 4.6 m (15 ft) of soil. However, the presence of inorganics or organics in the overlying gravel is unknown.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate for the current conditions at the site.

3.3.4.6 Qualitative Discussion of the Threat Posed by the 116-H-3 French Drain. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Table 3-3c, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is > 1E-02 and is mainly attributable to cesium-137, cobalt-60, and europium-152 via the external pathway.

- For the occasional-use scenario, the estimated risk is 8E-05 and is mainly attributable to cesium-137, cobalt-60, and europium-152 via the external pathway.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-3d, is 5E-03 and is mainly attributable to cesium-137 via the external pathway.

The total estimated risks for the 116-H-3 waste site are based primarily on the historical data collected from the site. Because some of the risk-producing data available are historical data, the degree of confidence is medium to high for the types of contaminants present at the site even though LFI data exist. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the contaminant concentrations and the estimated risks is medium. The risks are based on scenarios that represent high-frequency use of the waste site and low-frequency use of the site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimate at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk for external exposure may be an overestimate at this waste site.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. At 116-H-3, the risk-driving contaminants are found primarily in the upper 6 ft of soil. Therefore, the external exposure risk can be calculated to exceed 1E-06 under the current occasional-use scenario. Radiological survey data do not indicate surface radiation levels elevated above background. This contradiction could be due to partial shielding by surface soils, masking by background radiation, and non-uniform contaminant distribution.

Based on the QRA, the threat posed by radionuclides in 1992 at 116-H-3 would be high under the frequent-use scenario and low under the occasional-use scenario. The threat posed by radionuclides under the frequent-use scenario in 2018 would be medium.

3.3.5 Qualitative Risk Assessment for the 116-H-3 French Drain - Ecological Evaluation

The total dose to the Great Basin Pocket Mouse from radionuclides present in soil at the 116-H-3 drain is shown in Table 3-3e and 3-3f for the 0-15 and 0-6 ft. soil interval, respectively. The total dose is 0.00032 and 0.0000083 rad/day for the 0-15 and 0-6 ft. soil intervals, respectively. Below the 6 ft. soil interval, all of dose is attributable to strontium-90. Above 6 ft. the dose is from Cs-137. No other constituents are identified in the waste site.

The radiological dose for both soil intervals is below the 1 rad/day benchmark.

3.4 THE 116-H-7 RETENTION BASIN

3.4.1 Historical Data for the 116-H-7 Retention Basin

The 116-H-7 retention basin is located in the southeast corner of the 100-HR-1 operable unit and measures 180 m x 83 m x 6 m (600 ft x 273 ft x 20 ft) deep and would have held approximately 95 million L (25 million gal) (see Figure 1-3). The basin has been backfilled to a depth of about 1.2 m (4 ft) above the floor and slopes to the top of the walls. This double-celled concrete lined basin received process effluents from the H reactor and retained cooling water effluent to allow for radioactive decay and cooling. The effluent was then discharged directly to the Columbia River. Decontamination wastes from the H reactor building drains were also pumped

to this basin by the 132-H-3 pumping station. The basin was active from 1945 to 1965. Sludge and waste from this basin were removed in 1953 and 1965. The material removed in 1953 was placed in the adjacent 116-H-7 sludge burial trench. Some of the sludge was removed in 1965 and deposited in 116-H-1 trench. The walls of retention basin were demolished and are now covered with soil.

In 1975, inventory of the basin samples (Dorian and Richards 1978) measured approximately 91 Ci with the sludge contributing approximately 60 Ci, the soil fill 18 Ci, and the concrete approximately 13 Ci. Results of the sludge analyses identified cobalt-60, cesium-134, cesium-137, europium-152, europium-154, europium-155, tritium, plutonium-238, plutonium-239/240, strontium-90 and uranium. Carbon-14 was not detected. Non-radiological chemical inventories have not been conducted. However, chromium (from sodium dichromate) has been identified by inventory in the 116-H-1 trench. Since the 116-H-1 trench received sludge material from the 116-H-7 retention basin, it is assumed that chromium is also present in the 116-H-7 retention basin. Historical data are presented in Appendix A.

3.4.2 LFI Data for the 116-H-7 Retention Basin

The LFI data collected for the 116-H-7 retention basin consists of one borehole drilled into the trench with five split soil samples collected beginning at 0.3 m (1 ft) below the ground surface to a depth of 6 m (20 ft) (see Figure 2-1). Borehole logs indicate approximately 1.8 m (6 ft) of sandy gravel fill currently overlie a concrete layer, presumably the basin floor. The samples were analyzed for radionuclides, PCBs, pesticides, TAL, and TCL analytes. In addition, three archive samples were collected from below 4.6 m (15 ft). All sample depths indicated are the top of the sampling interval. The borehole logs for the LFI data for this site indicate that radiation is less than detectable at ground surface to a depth of approximately 1.5 m (5 ft) then detectable from 1.5 m (5 ft) to 4.6 m (15 ft) with a maximum of 1100 cpm at approximately 4 m (13 ft).

Laboratory results identified radionuclides, inorganic and organic compounds. All sample data are evaluated for use in the preliminary screening process.

3.4.3 Data Summary for the 116-H-7 Retention Basin

The maximum concentrations of the historical radionuclide data reported at or above 4.6 m (15 ft), decayed to 1992, and the LFI data are summarized in Table 3-4a. The data have been compared and the maximum concentration from either historical data, decayed to 1992, or LFI data for any detected parameter is used in the QRA for current exposures. The maximum concentration is also decayed to 2018 for evaluation of future exposures.

The historical data are compared to the LFI data with the following items noted:

- Cesium-134, europium-155, plutonium-238 and tritium are reported as detects in the historical data, but are reported below detection or not analyzed for in the LFI data. The historical data are used in the QRA.

- Americium-241, carbon-14, potassium-40, radium-226, technetium-99, thorium-228, thorium-232, uranium-235, uranium-238, and zirconium-95 are either not reported or not detected in the historical data. The LFI data are used in the QRA.

- The inorganic and organic LFI data are evaluated in the QRA because no historical data exist for these parameters.

- Aluminum, calcium, iron, magnesium, potassium and sodium are eliminated from consideration in the QRA based on evaluation as recommended in HSBRAM (DOE-RL 1993a).

- Lead lacks toxicity data for risk calculation. Lead concentrations do not exceed the EPA soil cleanup guideline of 500-1,000 mg/kg.

3.4.4 Qualitative Risk Assessment for the 116-H-7 Retention Basin - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the contaminants of potential concern, the exposure and toxicity assessment and the risk characterization for the 116-H-7 retention basin.

3.4.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of inorganic parameters presented in Table 3-4a are compared to Hanford Site background concentrations, as discussed in Section 2.2. Barium, cobalt, copper, manganese, mercury, nickel, and vanadium concentrations are lower than the background concentrations and are eliminated from further evaluation in the QRA. The remaining inorganic, all organic, and radionuclide parameters that have been identified in Table 3-4a are carried through the preliminary risk-based screening.

Radionuclides that exceed screening criteria are indicated by shading on Table 3-4b while inorganic and organic constituents that exceed screening criteria are indicated by shading on Table 3-4c. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the 116-H-7 retention basin and are further evaluated in the QRA for both human health and environmental receptors.

3.4.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Intakes are provided for both noncarcinogenic and carcinogenic effects. Specific intakes are not presented if there are no slope factors (SFs) or chronic reference doses (RfDs) available to evaluate a contaminant of potential concern.

3.4.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for both noncarcinogenic and carcinogenic substances carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.4.4.4 Risk Characterization. The risk characterization is based upon information from the exposure assessment and toxicity assessment. It forms the basis for characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-7 retention basin. The risk characterization is conducted as described in Section 2.3. Calculated ICRs, HQs, and HIs are compared to an ICR of 1E-06 and an HQ or HI of 1. All ICRs exceeding 1E-06 and all HQs or HIs exceeding unity, are highlighted in Tables 3-4d, 3-4e, and 3-4f.

3.4.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying contaminants and concentrations for risk assessment. The LFI data for the 116-H-7 retention basin site are of known quality, are analyzed using EPA methods and are validated prior to use. However, the validated data have been reviewed and some rejected or estimated data have been included in the QRA. For instance, J (estimated values) are used and R (rejected values) are used if the reason for rejection is missing calibration sheets. None of the LFI radionuclide data used for the 116-H-7 retention basin QRA were rejected due to missing calibration sheets.

The historical data and LFI data, as presented in Table 3-4a, indicate differences. The LFI soil sampling data identifies contaminants throughout the length of the borehole from 0.3 m (1 ft) below ground surface (BGS) to 6 m (20 ft) BGS. Borehole logs documenting drilling activities indicate detectable radiation above background between 1.5 m (5 ft) and 4.6 m (20 ft) BGS. The historical data reports higher radionuclide concentrations, decayed to 1992 from 1 m (3 ft) to 1.5 m (5 ft) BGS where the LFI survey indicated no radiation above background. This is may be due to differing depths of fill material at present than existed when the historical data were collected or to the fact that data from a single borehole may not be representative of sitewide conditions.

The historical data associates elevated levels of radionuclides primarily with sludge remaining in the basin. There is no evidence that sludge has been removed from the basin since the historical data were collected. Thus, the historical data are used to characterize risk in this QRA.

The contaminants and concentrations identified in the LFI data are not necessarily representative of the upper 4.6 m (15 ft) of soil. The concentrations of the contaminants identified may be under or overestimated since only one borehole was drilled for sampling. "Hot spots" may be present in the 116-H-7 retention basin that were not sampled. The possibility exists that contaminants may be present other than those identified.

The risks estimated in this QRA are based on the maximum concentrations detected in the LFI and historical data above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740 (6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

Historical data for chemical (non-radiological) constituents are not available, and as such, no comparisons between the two are made. The LFI data have been used for all inorganic and organic parameters in the QRA.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion, and inhalation. The 116-H-7 retention basin is reported to be filled with gravel with a concrete layer at 1.8 m (6 ft). Exposure to contaminants that are 1 to 1.5 m (3 to 5 ft) or more BGS would require some excavation. The risks of exposure, should contact with the contamination be reached, would be as

estimated for this QRA. A primary uncertainty, however, is what contaminants may be present in the overlying gravel fill which exists today. Based on LFI survey data, radionuclides are not currently present above field detection levels.in the upper 1.5 m (5 ft) of soil. However, the presence of inorganics or organics in the overlying gravel is unknown.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate for the current conditions at the site.

3.4.4.6 Qualitative Discussion of the Threat Posed by the 116-H-7 Retention Basin. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Tables 3-4d and 3-4f, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is > 1E-02 and is mainly attributable to cesium-137, cobalt-60, europium-152, and europium-154 via the external pathway.

- For the occasional-use scenario, the estimated risk is > 1E-02 and is mainly attributable to cobalt-60, europium-152, and europium-154 via the external pathway.

Non-radioactive contaminants:

- For the frequent- and occasional-use scenarios, the estimated risks are 1E-04 (HI = 2) and 2E-06 (HI =0.04), respectively, mainly attributable to arsenic via the soil ingestion pathway.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-4e, is > 1E-02 and is mainly attributable to cesium-137, cobalt-60, europium-152, and europium-154 via the external pathway.

The total estimated risks for the 116-H-7 retention basin are based primarily on the historical data collected from the site. The degree of confidence is high for the types of contaminants present at the site. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the contaminant concentrations and the estimated risks is low. The risks are based on scenarios that represent high-frequency use of the waste site and low-frequency use of the site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimate at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk for external exposure may be an overestimate at this waste site.

The current occasional use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. At the 116-H-7 retention basin, the risk-driving

contaminants are found primarily in the upper 1.8 m (6 ft) of soil. Therefore, the external exposure risk can be calculated to exceed 1E-06 for occasional-use of the site in 1992. This conclusion is supported by radiological survey data which indicates surface radiation levels elevated above background.

Based on the QRA, the threat posed by radionuclides in 1992 at the 116-H-7 retention basin would be high under the frequent-use scenario and high under the occasional-use scenario as well. The threat posed by radionuclides under the frequent-use scenario in 2018 would also be high. The threat posed by non-radioactive contaminants would be medium under the frequent-use scenario and low under the occasional-use scenario.

3.4.5 Qualitative Risk Assessment for the 116-H-7 Retention Basin - Ecological Evaluation

The total dose to the Great Basin Pocket Mouse from radionuclides present in soil at the 116-H-7 retention basin is shown in Tables 3-4g. The total dose is 20 rad/day for both the 0-6 and 6-15 ft. soil intervals, of which 99% of the dose is attributable to strontium. The daily dose from arsenic, chromium, lead, and zinc is 1.17 0.13, 15 and 77 mg/kg/day, respectively. Arsenic and lead are from the 0-6 ft. soil interval.

The radiological dose is above the 1 rad/day benchmark and the dose from arsenic and lead and zinc is above the NOEL for the Great Basin Pocket Mouse.

3.5 THE 116-H-9 CRIB

3.5.1 Historical Data for the 116-H-9 Crib

The 116-H-9 crib is a disposal cubicle with dimensions of approximately 3 m x 3 m x 3 m deep (10 ft x 10 ft x 10 ft deep). It is located directly outside the security fence to the west of the H reactor building (see Figure 1-3). From 1960 to 1965 the crib received drainage from the 132-H-2 building seal pits. The radioactive effluents that drained to this crib had short half-lives, and the crib was released from radiological controls prior to 1967. The unit received approximately 300,000 L (79,500 gallons) of waste. The crib was sampled by Dorian and Richards (1978) and no contamination was detected above background levels. Currently, the site is filled with gravel and covered to grade with clean soil.

3.5.2 LFI Data for the 116-H-9 Crib

The LFI data collected for the 116-H-9 drainage crib consists of one borehole drilled into the crib with three soil samples collected beginning at 1 m (3 ft) below the ground surface to a depth of 7.3 m (22 ft) (see Figure 2-1). In addition, 3 split tube samples and six archive soil samples were also collected beginning at a depth of 1 m (3 ft). All sample depths indicated are the top depth of the sampling interval. The borehole logs for the LFI data for this site indicate that radiation is less than detectable throughout the borehole.

Laboratory results identified radionuclides and inorganic parameters. All sample data are evaluated for use in the preliminary screening process.

3.5.3 Data Summary for the 116-H-9 Crib

No historical data were available for comparison to the LFI data. The maximum concentrations of the LFI data are summarized in Table 3-5a and used in the QRA.

The following items are noted for the LFI data:

- Cesium-137 is eliminated from consideration in the QRA as it was only detected below 4.6 m (15 ft).

- All organic compounds are reported below the detection limit and are not presented in Table 3-5a. Concentrations of inorganic constituents generally decreased with depth, the maximum concentrations were always associated with the shallowest sample depth, 1 m (3 ft).

- Aluminum, calcium, iron, magnesium, potassium and sodium are eliminated from consideration in the QRA based on evaluation as recommended in HSBRAM (DOE-RL 1993a).

3.5.4 Qualitative Risk Assessment for the 116-H-9 Crib - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the potential contaminants of concern, the exposure and toxicity assessment and the risk characterization for the 116-H-9 crib.

3.5.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of inorganic parameters presented in Table 3-5a are compared to Hanford Site background concentrations, as discussed in Section 2.2. Lead is detected in concentrations lower than the background concentration and is eliminated from further evaluation in the QRA. The remaining inorganic and radionuclide parameters that have been identified in Table 3-5a are carried through the preliminary risk-based screening.

Radionuclides that exceed screening criteria are indicated by shading on Table 3-5b while inorganic constituents that exceed screening criteria are indicated by shading on Table 3-5c. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the 116-H-9 crib and are evaluated further in the QRA for both human health and environmental receptors.

3.5.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Intakes are provided for both noncarcinogenic and carcinogenic effects. Specific intakes are not presented if there are no slope factors (SFs) or chronic reference doses (RfDs) available to evaluate a contaminant of potential concern.

3.5.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for both noncarcinogenic and carcinogenic substances carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.5.4.4 Risk Characterization. The risk characterization is based upon information from the exposure assessment and toxicity assessment. It forms the basis for characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-9 crib. The risk characterization is conducted as described in Section 2.3. Calculated ICRs, HQs, and HIs are compared to an ICR of 1E-06 and an HQ or HI of 1 for the 116-H-1 trench. All ICRs exceeding 1E-06 and all HQs or HIs exceeding unity, are highlighted in Tables 3-5d, 3-5e, and 3-5f.

3.5.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying contaminants and concentrations for risk assessment. The LFI data for the 116-H-9 crib are of known quality, are analyzed using EPA methods and are validated prior to use. However, the validated data have been reviewed and some rejected or estimated data have been included in the QRA. For instance, J (estimated values) are used and R (rejected values) are used if the reason for rejection is missing calibration sheets. None of the LFI radionuclide data used for the 116-H-9 crib QRA was rejected due to missing calibration sheets.

The contaminants and concentrations identified in the LFI data are not necessarily representative of the upper 4.6 m (15 ft) of soil. The concentrations of the contaminants identified may be under or overestimated since only one borehole was drilled for sampling. "Hot spots" may be present in the 116-H-9 crib that were not sampled. However, due to the small size of the waste site this source of uncertainty is not considered of great import for the 116-H-9 crib.

The risks estimated in this QRA are based on the maximum concentrations detected in the LFI and historical data above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administration Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740 (6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

Beryllium, chromium, cobalt, copper, nickel, vanadium and zinc, were not evaluated in the preliminary risk-based screening or for potential exposures via the fugitive dust inhalation pathway because RfDs are not available. However, beryllium and chromium were both evaluated for carcinogenic effects. Carcinogenic effects are generally associated with lower exposures.

Hexavalent chromium has been identified as a key contaminant for potential risk factors at this location. It should be noted that the concentrations used for determining this risk are based on total chromium analyses and it is likely that a major part of the chromium that is quantified and used in the QRA is trivalent chromium. The chromium in the sodium dichromate compound used

at this waste site is hexavalent chromium. Hexavalent chromium is considered unstable in most soils and is reduced to the less toxic trivalent chromium.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion, and inhalation. The 116-H-9 crib is reported to be filled with gravel and covered to grade with soil. However, maximum concentrations of some contaminants were detected in the overlying soil and gravel which exists today. Contact with contaminants may be possible if access to the crib area occurs.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate for the current conditions at the site.

3.5.4.6 Qualitative Discussion of the Threat Posed by the 116-H-9 Crib. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Tables 3-5d and 3-5f, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is 5E-04 and is mainly attributable to potassium-40 and thorium-228 via the external pathway.

- For the occasional-use scenario, the estimated risk is 3E-06 and is mainly attributable to potassium-40 and thorium-228 via the external pathway.

Non-radioactive contaminants:

- For the frequent- and occasional-use scenarios, the estimated risks are 6E-05 (HI = 2.5) and 1E-06 (HI = 0.21), respectively, mainly attributable to beryllium via the soil ingestion pathway and chromium VI via the fugitive dust inhalation pathway.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-5e, is 3E-04 and is mainly attributable to potassium-40 and radium-226 via the external pathway.

The total estimated risks for the 116-H-9 crib waste site are based on the LFI data collected from the site. The degree of confidence is high for the types of contaminants present at the site. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the contaminant concentrations and the estimated risks is also high. The risks are based on scenarios that represent high-frequency use of the waste site and low-frequency use of the site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimate at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk for external exposure may be an overestimate at this waste site. The ICR for this waste site includes risk attributable to potassium-40, a naturally occurring radionuclide not associated with human activities. Potassium-40 contributes two-fifths of the risk from radionuclides under the frequent-use scenario in 1992 and one-third of the risk under the

occasional-use scenario. In 2018, potassium-40 will contribute two-thirds of the risk attributable to radionuclides under the occasional-use scenario.

The current occasional-use scenario is·also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods.and results of this evaluation are provided in Appendix F. At 116-H-9, the risk-driving contaminants are found primarily in the upper 6 ft of soil. Therefore, the external exposure risk can be calculated to exceed 1E-06 under the occasional-use scenario in 1992. Radiological survey data does not indicate surface radiation levels elevated above background. This is probably due to masking by background radiation since potassium-40 is a major risk-driver at this site.

Based on the QRA, the threat posed by radionuclides in 1992 at 116-H-9 would be medium under the frequent-use scenario and low under the occasional-use scenario. The threat posed by radionuclides under the frequent-use scenario in 2018 would be medium. The threat posed by non-radioactive contaminants would be medium under the frequent-use scenario and low under the occasional-use scenario.

3.5.5 Qualitative Risk Assessment for the 116-H-9 Crib - Ecological Evaluation

The total dose rate to the Great Basin pocket mouse from radionuclides present in soil at the 116-H-9 crib is shown in Tables 3-5h and 3-5g for the soil intervals of 0-6 and 0-15 ft, respectively. The total dose rate (0.00023 rad/day) is below the EHQ of 1 rad/day for the Great Basin pocket mouse and includes both soil intervals. The calculated daily doses to the pocket mouse for barium, manganese, and vanadium (8.8, 67, and 0.19 mg/kg-day, respectively) are above the wildlife NOELs of 0.02, 0.01, and 0.07 mg/kg-day.

3.6 PROCESS EFFLUENT PIPELINES

3.6.1 Historical Data for the Process Effluent Pipelines

Process effluent pipelines emanate from the H reactor building and run to various process effluent disposal and treatment facilities. Process effluent pipelines also run from the 116-H-7 retention basin both to the Columbia River and to the 116-H-1 trench (see Figure 1-3). The lines are approximately 610 m (2,000 ft) long and 5.5 m (66 inches) in diameter, constructed of steel pipe and are buried approximately 6 m (20 ft) below the land surface. They are still in place. Portions of this transfer system lie beneath areas surrounded by security fences. Dorian and Richards (1978) indicated that soil contamination from past effluent pipeline leakage in the 116-H-7 area appears to be minimal. No measurable contamination was detected with a Geiger-Müller probe in the soil adjacent to the 116-H-7 effluent lines and junction boxes (Dorian and Richards 1978).

Limited radiological sampling has been performed on the pipelines by Dorian and Richards (1978). Two sets of historical data are presented in Table 3-6a, the maximum concentrations of radionuclides in the soil column along the effluent pipelines and the maximum concentrations of either the sludge from 116-H-7 retention basin or the sludge from inside the distribution box. Radionuclides detected in the soil/sludge sampling include cesium-134, cesium-137, cobalt-60,

europium-152, europium-154, europium-155, nickel-63, plutonium-238, plutonium-239/240, strontium-90, tritium, and uranium. Historical data are provided in Appendix A.

3.6.2 LFI Data for the Process Effluent Pipelines

No LFI data have been collected for this waste site and there are no analogous or related sites that have been sampled.

3.6.3 Data Summary for the Process Effluent Pipelines

The historical data from the soil column along the pipelines and the sludge from the inlet distribution box and 116-H-7 retention basin are used to perform the QRA. The maximum concentrations of the historical data, reported at or above 4.6 m (15 ft), decayed to 1992 and 2018 are summarized in Table 3-6a. Data from the soil column along the pipelines represent potential soil contamination from leaks that may have occurred along the pipelines while data from the sludge samples are assumed to be representative of waste material contained within the pipelines.

The two sets of historical data are compared with the following items noted:

- Only selected radionuclides were analyzed in the historical data.

- Inorganics and organic compounds were not analyzed.

- Cesium-134 and nickel-63 are not detected in the soil column data.

- Depths of soil column samples are not known, but it is assumed for the QRA that the parameters are present above 4.6 m (15 ft).

3.6.4 Qualitative Risk Assessment for the Process Effluent Pipelines - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the contaminants of potential concern, the exposure and toxicity assessments, and the risk characterization for the process effluent pipelines.

3.6.4.1 Identification of Contaminants of Potential Concern. The maximum concentrations of radionuclides that have been identified in Table 3-6a are carried through the preliminary risk-based screening. Results of the preliminary screening are summarized in Table 3-6b, radionuclides that exceed the screening criteria are indicated by shading. Those parameters exceeding the screening criteria are considered contaminants of potential concern for the process effluent pipelines and are carried through the QRA process.

3.6.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Intakes are provided for carcinogenic effects only. Specific intakes are not presented if there are no slope factors (SFs) available to evaluate a contaminant of potential concern.

3.6.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for radionuclides carried through the risk assessment are summarized in Tables B-1 and B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.6.4.4 Risk Characterization. The risk characterization is based upon the information from the exposure assessment and toxicity assessment. It forms the basis for the characterization of risks and human health hazards from potential exposures to contaminants of concern from the process effluent pipelines. The risk characterization is conducted as described in Section 2.3. Calculated ICRs are compared to an ICR of 1E-06. All ICRs exceeding 1E-06 are highlighted in Tables 3-6c and 3-6d.

3.6.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

Generally, it is preferred that like data (all of known quality, EPA methods and validated) be used when identifying the contaminants and concentrations for evaluation in the risk assessment. LFI data for the process effluent pipelines are not available, and there are no analogous or related sites sampled.

The risks estimated in this QRA are based on the maximum concentrations detected in the historical data above 4.6 m(15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740(6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion, and inhalation. The process effluent pipelines are reportedly buried under approximately 6 m (20 ft) of soil. Exposure to contaminants within the pipelines would require extensive excavation as well as opening of the pipeline itself. Potential exposures to process effluent pipeline leaks are evaluated using soil column sampling data. Sampling depth was not reported. It was assumed that samples were taken in the top 4.6 m (15 ft) of soil.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA do not currently occur at the site. Therefore, the QRA risk numbers do not represent actual risks and are an overestimate of the risk under current conditions.

3.6.4.6 Qualitative Discussion of the Threat Posed by the Process Effluent Pipelines. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Table 3-6c, are as follows:

Soil column exposure:

- For the frequent-use scenario, the estimated risk is 3E-05 and is mainly attributable to cobalt-60, europium-152, and europium-154 via the external pathway.

- For the occasional-use scenario, the estimated risk is 2E-07.

Sludge exposure:

- For the frequent-use scenario, the estimated risk is > 1E-02 and is mainly attributable to cesium-137, cobalt-60, europium-152, and europium-154 via the external pathway.

- For the occasional-use scenario, the estimated risk is > 1E-02 and is mainly attributable to cobalt-60 and europium-152 via the external pathway.

The total estimated risk from radionuclides in the soil column in 2018 for the frequent-use scenario, as shown in Table 3-6c, is 6E-06 and is mainly attributable to europium-152 via the external pathway. The total estimated risk from radionuclides in sludge in 2018 is > 1E-02 and is mainly attributable to cesium-137, cobalt-60, europium-152, and europium-154 via the external exposure pathway.

The total estimated risks for the process effluent pipelines from exposures to the soil column are based on historical soil column samples collected from along the effluent lines between the inlet and outlet of the 116-H-7 basin. The degree of confidence is medium for the type of contaminants present at the site. The risk estimates are based on the maximum detected concentration. The confidence in the representativeness of the concentration and the estimated risks is low. The risks are based on scenarios that represent high frequency use of the waste site and low frequency use of the waste site but not actual risks under current conditions.

Soil column data do not provide evidence that extensive leakage occurred in the 100-HR-1 operable unit process effluent pipelines. However, if leaks have occurred along the pipelines, data from the 100-BC-1 operable unit process pipelines demonstrate a total estimated risk for the frequent-use scenario of > 1E-02. This ICR is mainly attributable to cesium-137 and europium-152 via the external pathway (WHC 1993b).

Exposure to sludge material within the distribution box is unlikely unless there is access to the inside of the pipelines and accidental ingestion occurs. Also, since the sludge is contained within the pipelines, the exposures associated with a fugitive dust pathway for both frequent- and occasional-use scenarios is very unlikely.

The external pathway is associated with the highest risk estimates at this waste site. The assumptions used in evaluating the external pathway are very conservative, as discussed in Appendix F. Consequently, the risk from external exposure may be over-estimated for this waste site.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. Radioactive contaminants associated with process effluent pipeline sludge are not present within the upper 1.8 m (6 ft) of soil and so do not present exposure risks under the occasional-use scenario in 1992. The depths of contaminants associated with the soil column adjacent to the process effluent pipelines has not been established. There are no radiological survey data specifically for the process effluent pipelines.

Based on the QRA, the threat posed by radionuclides in 1992 at the process effluent pipelines would be low for the soil source and high for the sludge source under the frequent-use scenario. Under the occasional-use scenario in 1992, the threat would be very low for the soil source and high for the sludge source. The threat posed by radionuclides under the frequent-use scenario in 2018 would be low for the.soil source and high for the sludge source.

3.6.5 Qualitative Risk Assessment for the Process Effluent Pipelines - Ecological Evaluation

The total dose to the Great Basin Pocket Mouse from radionuclides present in soil, from maximum concentrations above 6 ft, is 0.0076 rad/day. Soil concentrations from 0-15 ft are considered to be the same as the 0-6 ft values. In addition to the pipeline soil dose, the inlet distribution box and basin fill sludge dose is 80 rad/day. No non-radiological contaminants are identified for this site.

The radiological dose from the sludge exceeds the 1 rad/day benchmark.

3.7 116-H-7 SLUDGE BURIAL TRENCH

3.7.1 Historical Data for the 116-H-7 Sludge Burial Trench

The 116-H-7 sludge burial trench is located to the east of the 116-H-7 retention basin, along the Columbia River in the southeast corner of the 100-HR-1 operable unit. The trench is not enclosed by the H reactor security fence (see Figure 1-3). Sludge from the 116-H-7 retention basin was removed in 1953 and 1965. The material removed in 1953 was placed in the 116-H-7 sludge burial trench. The sludge removed in 1965 was deposited in the 116-H-1 trench. No significant radioactive contamination was detected by Dorian and Richards (1978) in a boring sample at 4.6 m (15 ft) below grade at the sludge burial trench. Radiological analysis identified europium-154, europium-155 and strontium-90. Plutonium-238, plutonium-239/240, europium-152, cobalt-60, cesium-134, cesium-137 and carbon-14 were analyzed for but not detected (Dorian and Richards, 1978). The sludge burial trench was removed from radiological controls in 1965. Historical data are provided in Appendix A (sample C on Table A-1a).

3.7.2 LFI Data for the 116-H-7 Sludge Burial Trench

LFI data for the 116-H-7 sludge burial trench have not been collected and there are no analogous or related sites sampled. The 116-H-1 effluent disposal trench is not considered analogous because, in addition to sludge from the 116-H-7 retention basin the trench also received process effluents contaminated by fuel element ruptures.

3.7.3 Data Summary for the 116-H-7 Sludge Burial Trench

Only radionuclide data are available from the historical data. The QRA is conducted on the maximum concentrations of radionuclides detected in the historical data, decayed to 1992 and 2018, as summarized in Table 3-7a. The following items are noted:

- Historical data are reported for europium-154, europium-155, and strontium-90 at depths at or above 4.6 m (15 ft).

- Plutonium-238, plutonium-239/240, europium-152, cobalt-60, cesium-134, cesium-137, and carbon-14, were analyzed but not detected in the historical data.

- No inorganic and organic parameters are evaluated in the QRA because they are not available from historical data.

3.7.4 Qualitative Risk Assessment for the 116-H-7 Sludge Burial Trench - Human Health

This section presents a summary of the parameters identified in the soil at this waste site, the screening of contaminants for evaluation in the QRA, the potential contaminants of concern, the exposure and toxicity assessments and the risk characterization for the 116-H-7 sludge burial trench.

3.7.4.1 Identification of Contaminants of Potential Concern. The radionuclide parameters that have been identified in Table 3-7a are carried through the preliminary risk-based screening. Results of the preliminary screening are summarized in Tables 3-7b. The radionuclides that exceed screening criteria are indicated by shading in Table 3-7b.

Only europium-154 exceeds the screening criteria and is considered a contaminant of potential concern for the 116-H-7 sludge burial trench. It is evaluated further in the QRA.

3.7.4.2 Exposure Assessment. The exposure assessment is conducted as described in Section 2.3. The estimated intakes of contaminants of potential concern for the frequent- and occasional-use scenarios are presented in Appendix E. Intakes are provided for carcinogenic effects only.

3.7.4.3 Toxicity Assessment. The toxicity assessment is conducted as described in Section 2.3. The toxicity values and supporting information for carcinogenic substances carried through the risk assessment are summarized in Tables B-2 in Appendix B. A brief discussion of the primary toxic effects for each contaminant of potential concern is also provided in Appendix B.

3.7.4.4 Risk Characterization. The risk characterization is based upon the information from the exposure assessment and toxicity assessment. It forms the basis for the characterization of risks and human health hazards from potential exposures to contaminants of potential concern detected at the 116-H-7 sludge burial trench. The risk characterization is conducted as described in Section 2.3. Calculated ICRs are compared to an ICR of 1E-06 for the 116-H-7 disposal trench. All ICRs exceeding 1E-06 are highlighted in Tables 3-7c and 3-7d.

3.7.4.5 Risk Characterization Uncertainty Analysis. The risks presented in this risk characterization are considered qualitative and estimated with multiple assumptions made about sampling, data quality, exposures, toxicity and other variables.

The historical data, as presented in Table 3-7a indicate three radionuclides detected from one sample collected at approximately 4.6 m (15 ft) below the surface. The sampling location for the historical data was not determined. No analysis of soil at or above a 4.6 m (15 ft) depth is available for organics or inorganics.

The risks estimated in this QRA are based on the maximum concentrations detected in the historical data above 4.6 m (15 ft). For soil levels based on human exposure via direct contact, the Washington Administrative Code requires the assumption that a reasonable estimate of the depth of soil that could be excavated and distributed at the ground surface as a result of site development activities (e.g., building a basement) is from the ground surface to 4.6 m (15 ft) below the ground surface [WAC 173-340-740(6)(c)]. This assumption may overestimate current risks because institutional controls prevent intrusion at the waste site.

The underlying assumptions regarding exposure are that contaminants of potential concern are readily accessible for receptor contact via external exposure, ingestion and inhalation. The 116-H-7 sludge burial trench is reported to be backfilled with soil and exposure to the contaminants that are 4.6 m (15 ft) below the surface would require extensive excavation. The risks of exposure, should contact with the contamination be reached, would be as estimated for this QRA. A primary uncertainty, however, is what contaminants may be present in the overlying soil. Data for contaminant concentrations above 4.6 m (15 ft) are not available.

The frequent- and occasional-use exposure scenarios that have been evaluated for the purposes of this QRA using 1992 concentrations do not currently occur at the site. Therefore, the QRA risk estimates do not represent actual risks and are an overestimate of the risk under current conditions at the site.

3.7.4.6 Qualitative Discussion of the Threat Posed by the 116-H-7 Sludge Burial Trench. The estimated risks in 1992 and 2018 are summarized in the following paragraphs.

The total estimated risks in 1992, as shown in Table 3-6c, are as follows:

Radionuclides:

- For the frequent-use scenario, the estimated risk is 6E-06 and is attributable solely to europium-154 via the external pathway.

- For the occasional-use scenario, the estimated risk is 4E-08.

The total estimated risk from radionuclides in 2018 for the frequent-use scenario, as shown in Table 3-6d, is 8E-07.

The estimated risks for the 116-H-7 sludge burial trench are based on historical data collected from the site. Because the data are historical and from a single sample, the degree of confidence is medium to low for the types of concentrations present at the site. The risk estimates are based on the maximum detected concentrations. The confidence in the representativeness of the concentration and the estimated risks is low. The risks are based on scenarios that represent high-frequency use of the waste site and low-frequency use of the waste site but not actual risks under current conditions.

The external pathway is associated with the highest risk estimates at this waste site. The assumptions used in evaluating the external pathway are very conservative as discussed in Appendix F. Consequently, the risk from external exposure may be over estimated for the waste site.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. The methods and results of this evaluation are provided in Appendix F. At the 116-H-7 sludge burial trench, the risk-driving contaminants were detected below the upper 6 ft of soil. Therefore, the external exposure risk can be calculated to be less than 1E-06 under the occasional-use scenario in 1992. There are no radiological survey data specifically for the 116-H-7 sludge burial trench to indicate current surface radiation levels.

Based on the QRA, the threat posed by radionuclides in 1992 at the 116-H-7 sludge burial trench would be low under the frequent-use scenario and very low under the occasional-use scenario. The threat posed by radionuclides in 2018 under the frequent-use scenario would be very low.

3.7.5 Qualitative Risk Assessment for the 116-H-7 Sludge Burial Trench - Ecological Evaluation

The total dose to the Great Basin pocket mouse from maximum concentrations in the soil above 15 ft is 0.02 rad/day. The dose rate is below the EHQ of 1 rad/day benchmark for this site, and no non-radiological contaminants exceeded their NOEL.

3.8 THE 116-H-5 OUTFALL STRUCTURE

3.8.1 Historical Data for the 116-H-5 Outfall Structure

The 116-H-5 outfall structure was a compartmented concrete box that overflowed to the Columbia River via a concrete sluiceway. It is located directly to the north of the 116-H-7 retention basin and measures 113.4 m x 8.1 m x 4.2 m (378 x 27 x 14 ft) (see Figure 1-3). From 1949 to 1965, the outfall structure received treated process effluent from the 116-H-7 retention basin, directing them to the Columbia River through either dual 152 cm (60 in) steel discharge pipes or a basalt-covered spillway down the river bank. The spillway was apparently used during periods when the pipes were unable to accommodate the volume of effluent being discharged (Dorian and Richards 1978). The 116-H-5 outfall structure is now demolished, in situ, and backfilled with 3 m (10 ft) of soil, except for the spillway. Waste inventories or sample analyses have not been conducted for the 116-H-5 outfall structure. Potential radioactive contaminants for the 116-H-5 outfall structure include americium-241, cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, nickel-63, plutonium-238, plutonium-239/240, potassium-40, radium-226, strontium-90, thorium-228, thorium-232, uranium-235, uranium-238, and zirconium-95. Potential inorganic contaminants include arsenic, chromium VI, and lead. This list of potential contaminants was taken from 116-H-7 retention basin data and includes all contaminants of potential concern which were present above preliminary risk-based screening concentrations.

3.8.2 LFI Data for the 116-H-5 Outfall Structure

No LFI data for the 116-H-5 outfall structure have been collected.

3.8.3 Data Summary for the 116-H-5 Outfall Structure

Potential contaminants at the 116-H-5 outfall structure are evaluated by calculating risk-based concentrations for the frequent- and occasional-use scenarios as presented in Tables 3-8a and 3-8b. Risk-based concentrations are a function of the inherent toxicity of the contaminants and are not necessarily indicative of likely risk-driving contaminants.
Risk calculations were performed upon historical data for the 116-D-5 outfall structure, an analogous site at the 100-DR-1 operable unit. An evaluation of the risk at 116-D-5 will presented in Section 3.8.4. Results of the risk-based calculations are summarized in the following paragraphs.

Frequent-Use Scenario:

- Cobalt-60, cesium-134, radium-226, and thorium-228 are associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.0049, 0.0064, 0.0069, and 0.0074 pCi/g, respectively, via the external exposure pathway.

- Arsenic is associated with the lowest hazard quotient (HQ); 24 mg/kg via the soil ingestion pathway. Arsenic is associated with the lowest ICR among inorganics; 0.38 mg/kg via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations of lead.

Occasional-Use Scenario:

- Cobalt-60, cesium-134, radium-226, and thorium-228 are associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.76, 1.3, 1.1, and 1.2 pCi/g, respectively, via the external exposure pathway;

- Arsenic is associated with the lowest hazard quotient (HQ); 1300 mg/kg via the soil ingestion pathway. Arsenic is associated with the lowest ICR among inorganics; 20 mg/kg, via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations of lead.

3.8.4 Qualitative Risk Assessment for the 116-H-5 Outfall Structure - Human Health

Because there is no sampling information for the 116-H-5 outfall structure, the identification of potential contaminants is limited to process information. No other data or historical information has been identified at this time.

The QRA for this site is limited to the calculation of specific risk-based soil concentrations for the possible contaminants identified from the 116-H-7 retention basin. The risk-based concentrations are summarized in Table 3-8a and 3-8b.

The risk-driving contaminants at the 116-H-7 retention basin are europium-152, europium-154, cobalt-60, and cesium-137. It is reasonable to assume that these contaminants may also be of greatest concern at the 116-H-5 outfall structure which received effluent from the 116-H-7 retention basin.

The 116-D-5 outfall structure is an analogous site in the 100-DR-1 operable unit for which risks were calculated based upon historical data. Total risk associated with radionuclides in 1992 for the frequent- and occasional-use scenarios at 116-D-5 outfall structure are >1E-02 and 4E-04 respectively. The risks are primarily attributable to europium-152, cobalt-60, and europium-154 via the external exposure pathway. Total risk associated with the frequent-use scenario in 2018 at the 116-D-5 outfall structure is 1E-02. This risk is primarily attributable to europium-152 via the external exposure pathway. The qualitative risk rating for the 116-H-5 outfall structure is medium.

The key source of uncertainty for this waste site is the lack of information on what contaminants are actually present and their concentrations. The risk-driving contaminants at 116-D-5 and 116-H-7 are similar. Based upon process information and the 116-D-5 analogous site, it is reasonable to assume that these radionuclides may also be a significant source of risk at the 116-H-5 outfall structure.

3.8.4.1 Qualitative Discussion of the Threat Posed By the 116-H-5 Outfall Structure. Based on the information provided in Section 3.8.4 the degree of confidence in the contaminants is low. The degree of confidence in the concentrations of contaminants is also low. The most important pathway for potential frequent- and occasional-use exposures, based upon the 116-D-5 analogous site, is the external pathway for radionuclides. The external exposure pathway is also associated with the lowest soil concentrations in the 116-H-5 outfall structure risk-based calculations.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. No sampling data exists for the 116-H-5 outfall structure to determine whether radionuclides are present in the upper 6 ft. of soil. Radiological survey data indicate surface levels of radiation are not elevated above background.

3.8.5 Qualitative Risk Assessment for the 116-H-5 Outfall Structure - Ecological Evaluation

Waste unit 116-H-5 was not evaluated for qualitative risk because of insufficient data to complete an assessment.

3.9 THE 132-H-3 PUMP STATION

3.9.1 Historical Data for the 132-H-3 Pump Station

The 132-H-3 pump station is located in the southwest corner of the 100-HR-1 operable unit, within the H reactor building security fence, near the western edge of the H reactor building (see Figure 1-3). The pump station consisted of four sumps containing approximately 302,880 L (80,000 gallon) of water. At the time of de-commissioning in 1987, the basins also contained approximately 3,786 L (1,000 gallon) of sludge. This station collected and pumped water from the H reactor building drains, including the irradiated fuel storage drains, into the process effluent system to the 116-H-7 retention basin. The facility was in service from 1949 to 1965. In 1987, sump water was removed and trucked to the 1325-N liquid waste disposal unit in the 100-N Area. The sludge was put in drums and placed in the H reactor building and the 132-H-3 pump station was demolished in situ and backfilled with a minimum of 4.6 m (15 ft) of clean fill.

Sludge and water samples from four sumps in the 132-H-3 pump station were analyzed in 1987 before the pump station was decommissioned (Dorian and Richards 1978). Result of chemical analyses identified the inorganic constituents, aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, fluoride, iron, lead, lithium, magnesium, manganese, molybdenum, sodium, nickel, phosphor, strontium, titanium, vanadium, zinc, silver, selenium, mercury, osmium and strontium and the ions nitrate, sulfate, phosphate, and ammonium.

Radiological sampling using a Geiger-Müller probe measured up to 4,000 counts per minute (cpm) of activity along the pipelines and pumps within the pump station. Smear samples of beta contamination from the floors, walls and equipment ranged from less than 10 cpm/100 cm^2 up to a maximum of 3,000 cpm/100 cm^2. Radionuclides identified include carbon-14, cesium-137, cobalt-60, europium-152, plutonium-239/240, strontium-90, and tritium. Additional potentially present radionuclides were taken from the 116-H-7 retention basin and include americium-241, cesium-134, europium-154, europium-155, nickel-63, plutonium-238, radium-226, thorium-228, thorium-232, uranium-238, and zirconium-95. The historical data are presented in Appendix A.

3.9.2 LFI Data for the 132-H-3 Pump Station

No LFI data for the 132-H-3 pump station have been collected.

3.9.3 Data Summary for the 132-H-3 Pump Station

Potential contaminants at the 132-H-3 pump station are evaluated by calculating risk-based concentrations for the frequent- and occasional-use scenarios as presented in Tables 3-9a and 3-9b. Risk-based concentrations are a function of the inherent toxicity of the contaminants and are not necessarily indicative of likely risk-driving contaminants. Results of the risk-based calculations are summarized in the following paragraphs.

Frequent-Use Scenario:

- Cobalt-60, cesium-134, radium-226, and thorium-228 are associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.0049, 0.0064, and 0.0074 pCi/g, respectively, via the external exposure pathway.

- Arsenic and mercury are associated with the lowest hazard quotient (HQ); 24 mg/kg via the soil ingestion pathway. Arsenic associated with the lowest ICR among inorganics; 0.38 mg/kg via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations of lead.

Occasional-Use Scenario:

- Cobalt-60, cesium-134, radium-226, and thorium-228 are associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.76, 1.3, 1.1, and 1.2 pCi/g, respectively, via the external exposure pathway;

- Arsenic and mercury are associated with the lowest HQ; 1300 mg/kg via the soil ingestion pathway. Arsenic is associated with the lowest ICR among inorganics; 20 mg/kg, via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations of lead.

3.9.4 Qualitative Risk Assessment for the 132-H-3 Pump Station - Human Health

Because there are no soil sampling data for the 132-H-3 pump station, the identification of potential contaminants is limited to process information, surface smear samples for radionuclides, and water/sludge samples for inorganics. No other data or historical information has been identified at this time.

The QRA for this site is limited to the calculation of specific risk-based soil concentrations for the possible contaminants identified from the 116-H-7 retention basin and historical building and sump water samples. The risk-based concentrations are summarized in Table 3-9a and 3-9b.

The risk-driving contaminants at the 116-H-7 retention are europium-152, europium-154, cobalt-60, and cesium-137. It is reasonable to assume that these contaminants may also be of greatest concern at the 132-H-3 pump station which pumped effluent to the 116-H-7 retention basin. The qualitative risk rating for the 132-H-3 pump station is low.

The key source of uncertainty for this waste site is the lack of information on what contaminants are actually present and their concentrations. Aside from europium-154, all the risk-driving contaminants at the 116-H-7 retention basin were identified as well at the 132-H-3 pump station. It is reasonable to assume that if leakage occurred from the 132-H-3 pump station, these radionuclides may also be a significant source of risk at this site.

3.9.4.1 Qualitative Discussion of the Threat Posed by the 132-H-3 Pump Station.
Based on the information provided in Section 3.8.4 the degree of confidence in the contaminants is low. The degree of confidence in the concentrations of contaminants is also low. The most important pathway for potential frequent- and occasional-use exposures, based upon the contaminant risk-based soil concentrations, is the external pathway for radionuclides. A minimum of 4.6 m (15 ft) of clean fill is reported to exist over the demolished 132-H-3 pump station. In this case, current external exposure to radionuclides would be negligible, as would be current exposures via the soil ingestion and inhalation pathways.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. No sampling data exists for the 132-H-3 pump station to determine whether radionuclides are present in the upper 6 ft of soil. Radiological survey data specific to the 132-H-3 pump station do not exist.

3.9.5 Qualitative Risk Assessment for the 132-H-3 Pump Station - Ecological Evaluation

Waste unit 132-H-3 was not evaluated for qualitative risk because of insufficient data to complete an assessment.

3.10 116-H-6 RETENTION BASIN

3.10.1 Historical Data for the 116-H-6 Retention Basin

The 116-H-6 retention basins are located within the central portion of the 100-HR-1 operable unit, north of the H reactor complex (see Figure 1-3). This facility comprises four of the original 16 concrete water treatment basins that were used to store and treat (through solar evaporation) N reactor fuel fabrication wastes from the 300 Area that included routine and non-routine waste. Each basin measures 13.9 m x 10 m x 2.89 m (45.5 x 33 x 9.5 ft) deep and is separated from the subsidence basin by a redwood plank weir. The subsidence basin is 29 m (53.5 ft) long, 16.3 m (95 ft) wide and 5 m (16.5 ft) deep at the north end and 4.7 m (15.5 ft) deep at the south end. All basins had been used at one time or another, and contained various levels of sludge, liquid and crystalline wastes.

The total routine wastes discharged in these basins in 1985 was 9,620,000 L (2,542,000 gallons) and consisted of spent acid etch solutions (primarily nitric, sulfuric, hydrofluoric and chromic acids) generated by the nuclear fuel fabrication process. These acidic solutions were neutralized with excess sodium hydroxide before being transported to the 116-H-6 basins. Metal constituents (mostly in the forms of precipitates) include copper, silicon, zirconium, nickel, aluminum, chromium, manganese and uranium. Non-routine waste consisted of unused chemicals. Complete descriptions of these wastes and quantities can be found in *Interim Status Closure/Post Closure Plan 183-H Solar Evaporation Basins* (WHC 1988a).

Because the unit received wastes through 1985, it falls under the jurisdiction of RCRA interim status TSD requirements. For this reason, the 116-H-6 retention basin was not specifically included in the NPL nomination. Extensive characterizations of the waste within the basins and the local groundwater have been conducted pursuant to RCRA closure process (WHC 1988b). All waste material has been removed from the basin. As of November 1985, the basins no longer received waste. Current conditions of the basins before the closure is finalized are as follows: basin 1 and 4 have been cleaned and decontaminated; basin 2 and 3 have been washed down but not decontaminated. Uranium was identified at the 116-H-6 retention basin. Results of inorganic analyses on 116-H-6 basins waste identified aluminum, antimony, arsenic, barium, beryllium, boron, calcium, cadmium, chromium, chloride, cobalt, copper, fluoride, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, potassium, phosphorous, selenium, silicon, silver, sodium, strontium, thallium, tin, titanium, vanadium, zinc, and zirconium. The ions identified were nitrate, nitrite, sulfate, phosphate, and ammonium. Historical data are presented in Appendix A.

The decommissioning and RCRA closure program have been conducted in 1991 and a report of the sampling and analysis activities is pending. The closure has not been finalized and depends on several criteria to be met (WHC 1988b). The data will be compared and incorporated in the QRA for this unit upon completion of the report.

3.10.2 LFI Data for the 116-H-6 Retention Basin

There are no LFI data and no analogous or related sites have been sampled.

3.10.3 Data Summary for the 116-H-6 Retention Basin

WHC (1988a) lists inorganics and organic compounds that were analyzed at various times throughout the service of this facility. Specific risk-based concentrations for frequent- and occasional-use scenarios are calculated based on identified potential contaminants from the above historical data. These risk-based concentrations are summarized in Tables 3-10a and 3-10b for radioactive and non-radioactive parameters. Risk-based concentrations are a function of the inherent toxicity of the contaminants and are not necessarily indicative of likely risk-driving contaminants. Assuming evaporation occurred, volatile organic compounds are not considered in the calculation of risk-based concentrations. This assumption will be confirmed when the RCRA closure report for this site is completed. Non-volatile organics were not analyzed for. Results of the risk-based calculations are summarized in the following paragraphs.

Frequent-Use Scenario:

- Uranium was the only radionuclide identified. The lowest soil concentration of concern for a 1E-06 risk is 1.2 pCi/g via the external exposure pathway.

- Phosphorus, thallium oxide, arsenic, mercury, and antimony are associated with the lowest hazard quotients (HQ); 1.6, 5.6, 24, 24, and 32 mg/kg respectively, via the soil ingestion pathway. Beryllium and arsenic are associated with the lowest ICR among inorganics; 0.15 and 0.38 mg/kg via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations for chloride, lead, lithium, phosphate, silicon, sulfate, titanium, and zirconium.

Occasional-Use Scenario:

- The lowest uranium soil concentration of concern for a 1E-06 risk is 92 pCi/g via the fugitive dust inhalation pathway.

- Phosphorus, thallium oxide, arsenic, mercury, and antimony are associated with the lowest hazard quotients (HQ); 83, 290, 1300, 1300, and 1700 mg/kg, respectively, via the soil ingestion pathway. Beryllium and arsenic are associated with the lowest ICR among inorganics; 7.8 and 20 mg/kg, via the soil ingestion pathway.

- No toxicity data are available to estimate risk-based concentrations for chloride, lead, lithium, phosphate, silicon, sulfate, titanium, and zirconium.

3.10.4 Qualitative Risk Assessment for the 116-H-6 Retention Basin - Human Health

Because no soil sampling information for the 116-H-6 retention basin are currently available, the identification of potential contaminants is limited to basin waste samples.

The QRA for this site is limited to the calculation of specific risk-based soil concentrations for the possible contaminants identified in the 116-H-6 basin wastes. The risk-based concentrations are summarized in Table 3-10a and 3-10b. The qualitative risk rating for the 116-H-6 retention basin is medium.

The key source of uncertainty for this waste site is the lack of information on what contaminants are actually present at the site today and their concentrations. Once the RCRA closure report for 116-H-6 is completed, soil concentrations of identified parameters can be used to estimate current and future risks associated with the 116-H-6 retention basin.

3.10.4.1 Qualitative Discussion of the Threat Posed By the 116-H-6 Retention Basin. Based on the information provided in Section 3.10.4 the degree of confidence in the contaminants is low. The degree of confidence in the concentrations of contaminants is also low. The most important pathway for potential frequent- and occasional-use exposures, based upon the contaminant risk-based soil concentrations, is the soil ingestion pathway for inorganic constituents.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. No sampling data exist for the 116-H-6 retention basin to determine whether radionuclides are present in the upper 6 ft. of soil. Radiological survey data indicate surface levels of radiation are not elevated above background.

3.10.5 Qualitative Risk Assessment for the 116-H-6 Retention Basin - Ecological Evaluation

Waste unit 116-H-6 was not evaluated for qualitative risk because of insufficient data to complete an assessment.

3.11 132-H-2 BUILDING

3.11.1 Historical Data for the 132-H-2 Building

The 132-H-2 building was located approximately 24 m (80 ft) southwest of the H reactor building (see Figure 1-3). The 132-H-2 building was a reinforced concrete structure, 18 m (59 ft) long, 12 m (39 ft) wide, and 11 m (35 ft) high, with a typical wall thickness of 0.4 m (15 inches). Ninety percent of the structure was built below ground level. The 132-H-2 building was built in 1960 to filter the H reactor exhaust air before it was routed to the 132-H-1 stack. The 132-H-2 building was built on the site of the 116-H-4 crib. The 132-H-2 building was demolished and the site leveled with clean soil in 1983. All contaminated rubble was buried at least 1 m (3 ft) deep. The rubble from the 132-H-2 building seal pits was buried under a minimum of 4.6 m (15 ft) of clean soil.

Prior to demolition, radiation surveys and isotopic analyses of concrete and paint were made. The total estimated inventory was 0.41 millicuries of radionuclide activity. Radionuclides identified include tritium, carbon-14, cobalt-60, strontium-90, cesium-137, europium-152, europium-154, and plutonium-239/240 (Powers 1986). The Allowable Residual Contamination Levels (ARCL) calculation report for the 132-H-2 building has been completed (Beckstrom 1984) but was not obtained for the QRA. An equivalent ARCL calculation report for the 132-D-2 building (Beckstrom and Loveland 1986), an analogous facility from the 100-DR-1 operable unit, is available and will be discussed in Section 3.11.4.

3.11.2 LFI Data for the 132-H-2 Building

No LFI data have been collected at the 132-H-2 building and there are no analogous or process related sites that have been sampled as part of the LFI.

3.11.3 Data Summary for the 132-H-2 Building

Potential contaminants at the 132-H-2 building are evaluated by calculating risk-based concentrations for the frequent- and occasional-use scenarios as presented in Table 3-11. Risk-based concentrations are a function of the inherent toxicity of the contaminants and are not necessarily indicative of likely risk-driving contaminants. Results of the risk-based calculations are summarized in the following paragraphs.

· Frequent-Use Scenario:

- Cobalt-60 is associated with the lowest soil concentration of concern for a 1E-06 risk; 0.0049 via the external exposure pathway.

Occasional-Use Scenario:

- Cobalt-60 is associated with the lowest soil concentration of concern for a 1E-06 risk; 0.76 via the external exposure pathway.

3.11.4 Qualitative Risk Assessment for the 132-H-2 Building - Human Health

The QRA for this site is limited to the calculation of risk-based concentrations for the possible contaminants identified in the 132-H-2 building before the building was demolished and buried in-situ, as based on the decommissioning report. The risk-based concentrations are summarized in Table 3-11. The qualitative risk rating for the 132-H-2 building is low.

The exposure assessment is based on assumptions regarding exposure conditions. A conservative assumption is made that the contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion and inhalation. The rubble from the 132-H-2 building is reportedly buried at least 1 m (3 ft) deep so that exposure to potential contaminants would require some excavation. The frequent- and occasional-use exposure scenarios that have been evaluated in this QRA do not currently occur at the site. The key source of uncertainty in this QRA is the lack of information on what contaminants are actually present and their concentrations.

3.11.4.1 Qualitative Discussion of the Threat Posed by the 132-H-2 Building. Based on the information provided in Section 3.11.4, the degree of confidence in the contaminants is low. The confidence in the concentrations of contaminants is also low. The most important pathway for potential frequent- and occasional-use exposures, based upon the contaminant risk-based soil concentrations, is the external pathway for radionuclides. However, since the building was demolished and buried in situ, and reportedly covered with 1 m (3 ft) of clean fill, the likelihood of current exposure via this pathway is reduced.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. No sampling data exists for the 132-H-2 building to determine if radionuclides are present in the upper 6 ft of soil. Radiological survey data specific to the 132-H-2 building have not been identified.

The ARCL report for the 132-H-2 building is not available for review for this QRA. The 132-D-2 ARCL report, however, can provide information for evaluation purposes. The radionuclides detected are the same for both sites. The radionuclide inventory of 132-D-2 building is 0.55 mCi while the 132-H-2 building has an inventory of 0.41 mCi.

The estimated ARCL dose rate for 132-D-2 is 1.7 mrem/yr. For an exposure duration of 30 yrs, the total absorbed dose would be 51 mrem. Using an EPA (1989a) risk factor of 6.2E-07 mrem/yr, this dose is associated with a lifetime cancer incidence risk of 3E-05. This risk is estimated using very conservative assumptions. The ARCL frequent-use scenario is based on a maximally exposed individual (MEI), not the reasonable maximum exposure (RME) concept used in the QRA (DOE-RL 1993a). Therefore, the dose rate provided in the ARCL report is expected to provide an upper bound exposure estimate. In addition, radioactive decay has occurred since the ARCL calculations were performed in 1986.

3.11.5 Qualitative Risk Assessment for the 132-H-2 Building - Ecological Evaluation

Waste site 132-H-2 was not evaluated for the qualitative risk because of insufficient data to complete an assessment.

3.12 THE 132-H-1 STACK

3.12.1 Historical Data for the 132-H-1 Stack

The 132-H-1 stack was a reinforced concrete stack measuring 60.96 m x 5.05 m (200 ft x 16 ft), located directly to the southwest of the H reactor building. The stack was demolished in 1983. A documented release of radionuclides from the stack in 1955 was reported. A ruptured fuel element burned briefly during discharge, resulting in radioactive stack emissions. Ground-level contamination approached 12 radioactive particles/9.29 m^2 (12 radioactive particles/100 ft^2) ranging from 1,000 to 10,000 counts/min and up to 700 mrad/h. The contamination spread south over approximately 18 km^2 (7 mi^2). Contaminated soil was removed and disposed of in an unspecified burial trench, as reported by ERDA (1975). The release included 0.8 Ci of barium, rare earth elements, and yttrium. The present location of the removed soil is unknown (ERDA, 1975).

After the demolition of the stack in 1983, about one-third of the foundation rubble was buried in a trench located between the demolished 132-H-2 building and 132-H-3 pump station. The remainder of the foundation was buried in place and covered with at least 1 m (3 ft) of clean fill. Five concrete core samples were taken from the stack in 1983 and 1987 (Beckstrom 1987) and analyzed for tritium, carbon-14, cobalt-60, strontium-90, cesium-137, europium-152, europium-154 and gross alpha. With the exception of europium-154, all constituents analyzed for were detected. The ARCL calculations for decommissioning the 132-H-1 stack (Beckstrom 1987) reported total radionuclide inventory in the buried rubble sample of 132-H-1 stack to be approximately 12 mCi.

3.12.2 LFI Data for the 132-H-1 Stack

No LFI data for the 132-H-1 stack have been collected and no analogous or related sites were sampled.

3.12.3 Data Summary for the 132-H-1 Stack

Potential contaminants at the 132-H-1 stack are evaluated by calculating risk-based concentrations for the frequent- and occasional-use scenarios as presented in Table 3-12. Risk-based concentrations are a function of the inherent toxicity of the contaminants and are not necessarily indicative of likely risk-driving contaminants. Results of the risk-based calculations are summarized in the following paragraphs.

Frequent-Use Scenario:

- Cobalt-60 is associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.0049 via the external exposure pathway.

Occasional-Use Scenario:

- Cobalt-60 is associated with the lowest soil concentrations of concern for a 1E-06 risk; 0.76 via the external exposure pathway.

3.12.4 Qualitative Risk Assessment for the 132-H-1 Stack - Human Health

The QRA for this site is limited to the calculation of risk-based concentrations for the possible contaminants identified in the 132-H-1 stack before the stack was demolished and buried in-situ, as based on the decommissioning report. The risk-based concentrations are summarized in Table 3-12. The qualitative risk rating for the 132-H-1 stack is low.

The exposure assessment is based on assumptions regarding exposure conditions. A conservative assumption is made that the contaminants of potential concern are readily accessible for receptor contact via external exposure, soil ingestion and inhalation. The rubble from the 132-H-1 exhaust stack is reportedly buried at least 1 m (3 ft) deep so that exposure to the potential contaminants would require some excavation. The frequent- and occasional-use scenarios that have been evaluated in this QRA do not currently occur at the site.

The key source of uncertainty in this QRA is the lack of information on what contaminants are actually present and their concentrations.

3.12.4.1 Qualitative Discussion of the Threat Posed by the 132-H-1 Stack. Based on the information provided in Section 3.12.4, the degree of confidence in the contaminants is low. The confidence in the concentrations of contaminants is also low. The most important pathway for potential frequent- and occasional-use exposures, based upon the contaminant risk-based soil concentrations, is the external pathway for radionuclides. However, the existing rubble was buried in situ and covered with at least 1 m (3 ft) of clean fill. The likelihood of current exposure via the external exposure pathway is therefore reduced.

The current occasional-use scenario is also evaluated for the external radiation exposure pathway while accounting for the shielding effect of soil. No sampling data exists for the 132-H-1 stack to determine if radionuclides are present in the upper 6 ft of soil. Radiological survey data specific to the 132-H-1 stack have not been identified.

The estimated ARCL dose rate for 132-H-1 stack is 4.8 mrem/yr (Beckstrom 1987). For an exposure duration of 30 yrs, the total absorbed dose would be 144 mrem. Using an EPA (1989a) risk factor of 6.2E-07 mrem/yr, this dose is associated with a lifetime cancer incidence risk of 9E-05. This risk is estimated using very conservative assumptions. The ARCL frequent-use scenario is based on a maximally exposed individual (MEI), not the reasonable maximum exposure (RME) concept used in the QRA (DOE-RL 1993a). Therefore, the dose rate provided in the ARCL report is expected to provide an upper bound exposure estimate. In addition, radioactive decay has occurred since the ARCL calculations were performed in 1986.

3.12.5 Qualitative Risk Assessment for the 132-H-1 Stack - Ecological Evaluation

Waste unit 132-H-1 was not evaluated for the qualitative risk because of insufficient data to complete an assessment.

3.13 THE 116-H-4 CRIB

3.13.1 Historical Data for the 116-H-4 Crib

The 116-H-4 crib was located southwest of and adjacent to the 132-H-3 pump station. The dimensions of the crib are 1.2 m x 1.2 m x .6 m deep (4 x 4 x 2 ft). The 116-H-4 crib received cooling water flow and discharge during periods of fuel element failure; approximately 7.6 L/min (2 gal/min). This crib was in service from 1950 to 1952, at which time it was covered with 0.6 m (2 ft) of soil (Stenner et al 1988). The Waste Information Data System (WIDS) reports that 3 m (10 ft) of soil covers the 116-H-4 crib (DOE-RL 1992b). In the early 1960's, the 116-H-4 crib was excavated and the material buried in the 118-H-5 burial ground. Approximately 1,000 kg (2,200 lb) of sodium dichromate were disposed of in the 116-H-4 crib. There is no radionuclide inventory of the exhumed 116-H-4 crib. In 1960, the 132-H-2 building was built on the same location as the 116-H-4 crib. After it was retired, the building was demolished and buried in-situ. The 132-H-2 building was a concrete structure, 18 m (59 ft) long, 12 m (39) ft wide and 11 m (35 ft) high, of which 90% was below grade (Powers 1986).

3.13.2 LFI Data for the 116-H-4 Crib

No LFI data have been collected for this waste site. The 116-H-4 crib was similar to the pluto cribs of the B, D, DR, and F Areas. However, the waste material has been removed from 116-H-4 and moved to the 118-H-5 burial ground. Demolished material from the 132-H-2 filter building is buried in the same location. There are no analogous or related sites that represent the present condition of the 116-H-4 crib.

3.13.3 Data Summary for the 116-H-4 Crib

Since construction of the 132-H-2 building involved excavation of the crib to a depth of approximately 9 m (30 ft), the risk associated with the 116-H-4 crib is likely to have been superseded by the risk associated with the 132-H-2 building waste site. Section 3.11 discusses the qualitative risk assessment for the 132-H-2 building. The qualitative risk rating for the 116-H-4 crib is low.

3.13.4 Qualitative Risk Assessment for the 116-H-4 Crib - Ecological Evaluation

Waste unit 116-H-4 was not evaluated for the qualitative risk because of insufficient data to complete an assessment.

Table 3-1a. Historical and LFI Data Summary for the 116-H-1 Trench. (Sheet 1 of 4)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Americium-241	-	432	-	-	0.2	10	0.2	0.2	maximum concentration detected at or above 15 ft.
Carbon-14	-	5,700	-	-	(15)	(19)	-	-	not detected at or above 15 ft.
Cesium-134	0.038 (0.04)	2.06	0.00017 (0.00018)	5 (25)	-	-	0.00017	2.8E-06	maximum concentration detected at or above 15 ft.
Cesium-137	580	30.2	400	2	32 (36.4)	10 (16)	400	220	maximum concentration detected at or above 15 ft.
Cobalt-60	280 (440)	5.2	33 (52)	2 (18)	2.5	10	33	1.1	maximum concentration detected at or above 15 ft.
Europium-152	1,200 (2,100)	13.6	530 (930)	2 (17)	54	10	530	140	maximum concentration detected at or above 15 ft.
Europium-154	310 (2,500)	8.8	88 (710)	2 (17)	5.4	10	88	11	maximum concentration detected at or above 15 ft.
Europium-155	42 (93)	4.9	4.4 (10)	2 (18)	-	-	4.4	0.12	maximum concentration detected at or above 15 ft.
Plutonium-238	0.32 (0.35)	87.8	0.28 (0.3)	2 (18)	-	-	0.28	0.23	maximum concentration detected at or above 15 ft.
Plutonium-239/240	6.6 (11)	24,000	6.6 (11)	2 (17)	0.74	10	6.6	6.6	maximum concentration detected at or above 15 ft.
Potassium-40	-	1.3E+09	-	-	13	15	13	13	maximum concentration detected at or above 15 ft.
Radium-226	-	1,600	-	-	0.78 (0.85)	15 (17)	0.78	0.77	maximum concentration detected at or above 15 ft.
Sodium-22	-	2.6	-	-	(1.78)	(16)	-	-	not detected at or above 15 ft.
Strontium-90	52 (82)	28	35 (55)	2 (17)	6.2	15	35	19	maximum concentration detected at or above 15 ft.

WHC-SD-EN-RA-004, Rev. 0

3T-1a-a

Table 3-1a. Historical and LFI Data Summary for the 116-H-1 Trench. (Sheet 2 of 4)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Technetium-99	-	2.13E+05	-	-	0.25 (0.67)	14 (17)	0.25	0.25	maximum concentration detected at or above 15 ft.
Thorium-228	-	1.91	-	-	0.95	14	0.95	7.6E-05	maximum concentration detected at or above 15 ft.
Thorium-232	-	1.41E+10	-	-	(0.89)	(19)	-	-	not detected at or above 15 ft.
Tritium	0.97	12.3	0.39	15	-	-	0.39	0.091	maximum concentration detected at or above 15 ft.
Uranium-233/234	-	2.4E+05	-	-	0.53 (0.62)	15 (17)	0.53	0.53	maximum concentration detected at or above 15 ft.
Uranium-235	-	7.0E+08	-	-	(0.0016)	(16)	-	-	not detected at or above 15 ft.
Uranium-238	-	4.5E+09	-	-	0.61	10	0.61	0.61	maximum concentration detected at or above 15 ft.
Total Uranium	0.31	4.5E+09	0.31	-	-	-	-	-	individual isotopes evaluated from LFI data
Inorganics, mg/kg									
Aluminum	-	-	-	-	7,500	14	.c		eliminated based on HSBRAM[c]
Arsenic	-	-	-	-	37.9	10	37.9		maximum concentration detected at or above 15 ft.
Barium	-	-	-	-	74.5	14	.d		eliminated based on comparison to background[d]
Calcium	-	-	-	-	5,520	14	.c		eliminated based on HSBRAM[c]
Chromium	-	-	-	-	18.9 (29.6)	14 (17)	.d		eliminated based on comparison to background[d]
Cobalt	-	-	-	-	8.3 (9.9)	14 (24)	.d		eliminated based on comparison to background[d]
Copper	-	-	-	-	19.5 (29.54)	14 (17)	.d		eliminated based on comparison to background[d]

WHC-SD-EN-RA-004, Rev. 0

Table 3-1a. Historical and LFI Data Summary for the 116-H-1 Trench. (Sheet 3 of 4)

Parameter	Historical Data[a]				LFI Data		QRA Data	
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Iron	-	-	-	-	16,900 (18,700)	14 (24)	-[c]	eliminated based on HSBRAM[c]
Lead	-	-	-	-	187	10	187	maximum concentration detected at or above 15 ft.
Magnesium	-	-	-	-	4,630	14	-[c]	eliminated based on HSBRAM[c]
Manganese	-	-	-	-	292	14	-[d]	eliminated based on comparison to background[d]
Mercury	-	-	-	-	(0.05)	(16)	-	not detected at or above 15 ft.
Nickel	-	-	-	-	11.5 (13.9)	14 (16)	-[d]	eliminated based on comparison to background[d]
Potassium	-	-	-	-	1,320	10	-[c]	eliminated based on HSBRAM[c]
Vanadium	-	-	-	-	35.8 (51)	14 (24)	-[d]	eliminated based on comparison to background[d]
Zinc	-	-	-	-	53.1	14	-[d]	eliminated based on comparison to background[d]
Organics, μg/kg								
Acenaphthene	-	-	-	-	210	14	210	maximum concentration detected at or above 15 ft.
Anthracene	-	-	-	-	430	14	430	maximum concentration detected at or above 15 ft.
Benzo(a)anthracene	-	-	-	-	940	14	940	maximum concentration detected at or above 15 ft.
Benzo(b)fluoranthene	-	-	-	-	890	14	890	maximum concentration detected at or above 15 ft.
Benzo(k)fluoranthene	-	-	-	-	760	14	760	maximum concentration detected at or above 15 ft.
Benzo(g,h,i)perylene	-	-	-	-	410	14	410	maximum concentration detected at or above 15 ft.
Benzo(a)pyrene	-	-	-	-	810	14	810	maximum concentration detected at or above 15 ft.
Bis(2-ethylhexyl) phthalate	-	-	-	-	68	-	68	maximum concentration detected at or above 15 ft.

Table 3-1a. Historical and LFI Data Summary for the 116-H-1 Trench. (Sheet 4 of 4)

| Parameter | Historical Data[a] | | | | LFI Data | | QRA Data | |
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Chrysene	-	-	-	-	920	14	920	maximum concentration detected at or above 15 ft.
Dibenzofuran	-	-	-	-	130	14	130	maximum concentration detected at or above 15 ft.
Fluoranthene	-	-	-	-	1,800	14	1800	maximum concentration detected at or above 15 ft.
Fluorene	-	-	-	-	190	14	190	maximum concentration detected at or above 15 ft.
Indeno(1,2,3-CD) pyrene	-	-	-	-	520	14	520	maximum concentration detected at or above 15 ft.
2-Methylnaphthalene	-	-	-	-	42	14	42	maximum concentration detected at or above 15 ft.
Phenanthrene	-	-	-	-	1,500	14	1500	maximum concentration detected at or above 15 ft.
Pyrene	-	-	-	-	1,200	14	1200	maximum concentration detected at or above 15 ft.

( ) indicates maximum concentration detected at depths greater than 15 ft.
ND indicates analyzed for but not detected.
- indicates parameter was not analyzed for or not reported.
[a] Dorian and Richards 1976 radiological data (1978).
[b] Depth indicated is the top of the sampling depth.
[c] Al, Ca, Fe, Mg, K, and Na are eliminated from further consideration as recommended in HSBRAM (DOE-RL 1993a).
[d] Maximum concentration compared to contaminant specific 95% UTL on Table 2-1 and eliminated because it did not exceed background.

Table 3-1b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-1 Trench.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
Americium-241	0.2	2.4E-10	0.32	3.2E-08	0.29	4.9E-09	0.68
Cesium-134	0.00017	4.1E-11	1.9	2.8E-11	330	5.2E-06	0.00064
Cesium-137	400	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	33	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	530	2.1E-12	36	1.1E-10	83	3.6E-06	0.00093
Europium-154	88	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	4.4	4.5E-13	170	1.8E-11	510	5.9E-06	0.056
Plutonium-238	0.28	2.2E-10	0.35	3.9E-08	0.23	2.8E-11	120
Plutonium 239/240	6.6	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120
Potassium 40	13	1.1E-11	6.9	7.6E-12	1,200	5.4E-07	0.0062
Radium-226	0.78	1.2E-10	0.63	3.0E-09	3	6.0E-06	0.00056
Strontium-90	35	3.6E-11	2.1	6.2E-11	150	_b_	_b_
Technetium-99	0.25	1.3E-12	59	8.3E-12	1,100	6.0E-13	5,600
Thorium-228	0.95	5.5E-11	1.4	7.8E-08	0.12	5.6E-06	0.0006
Tritium (H-3)	0.39	5.4E-14	1,400	7.8E-14	1.2E+05	_b_	_b_
Uranium 233/234	0.53	1.6E-11	4.8	2.7E-08	0.34	4.2E-11	79
Uranium-238	0.61	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
[b]Not an external exposure hazard
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 3-1c. Preliminary Risk-Based Screening for Non-Radioactive Soil Contaminants at the 116-H-1 Trench. (Sheet 1 of 2)

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at Oral HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at Inhalation HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)⁻¹	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF (mg/kg-d)⁻¹	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
INORGANICS										
Arsenic	37.9	3.0E-04ᵃ	2.4	_d	_d	1.7E+00ᵃ·ᵍ	0.038	5.0E+01ᵃ·ʰ	1.1	-
Lead	187	_d	_d	_d	_d	_d	_d	_d	_d	500-1000ᶠ
ORGANICS										
Acenaphthene	0.210	6.0E-02ᵃ	480	_d	_d	_e	_e	_e	_e	-
Anthracene	0.430	3.0E-01ᶜ	2,400	_d	_d	_e	_e	_e	_e	-
Benzo(a)anthracene	0.940	_d	_d	_d	_d	_d	_d	_d	_d	· ·
Benzo(b)fluoranthene	0.890	_d	_d	_d	_d	_d	_d	_d	_d	-
Benzo(k)fluoranthene	0.760	_d	_d	_d	_d	_d	_d	_d	_d	-
Benzo(g,h,i)perylene	0.41	3E-02ⁱ	240	_d	_d	_d	_d	_d	_d	-
Benzo(a)pyrene	0.810	_d	_d	_d	_d	7.3E+00ᵃ	0.0088	_d	_d	-
Bis(2-ethylhexyl)phthalate	0.068	1.4E-02ᵃ	4.6	_d	_d	_d	_d	_d	_d	-
Chrysene	0.920	_d	_d	_d	_d	_d	_d	_d	_d	-
Dibenzofuran	0.130	_d	_d	_d	_d	_e	_e	_e	_e	-
Fluoranthene	1.8	4.0E-02ᵃ	320	_d	_d	_e	_e	_e	_e	-
Fluorene	0.190	4.0E-02ᵃ	320	_d	_d	_e	_e	_e	_e	-
Indeno(1,2,3-CD)pyrene	520	_d	_d	_d	_d	_d	_d	_d	_d	-
2-Methylnaphthalene	0.042	4.0E-03ʲ	32	_d	_d	_d	_d	_d	_d	-
Phenanthrene	1.5	_d	_d	_d	_d	_e	_e	_e	_e	-

Table 3-1c. Preliminary Risk-Based Screening for Non-Radioactive Soil Contaminants at the 116-H-1 Trench. (Sheet 2 of 2)

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at Oral HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at Inhalation HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF (mg/kg-d)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
Pyrene	1.2	3.0E-02[a]	240	.d	.d	.e	.e	.e	.e	-

[a]Integrated Risk Information System (IRIS, EPA 1993).
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992).
[c]Superfund Technical Support Center (STSC 1992).
[d]No RfD or SF available to evaluate this pathway.
[e]Not classified as a carcinogen or not carcinogenic via this exposure route or pathway.
[f]EPA 1989.
[g]Based on proposed arsenic unit risk of 5E-05 μg/L (IRIS, EPA 1993).
[h]Based on 30% absorption of inhaled arsenic.
[i]Based on pyrene as a surrogate.
[j]Based on naphthalene surrogate.
- Not applicable
HQ = Hazard quotient
ICR = Lifetime incremental cancer risk
RfD = Chronic reference dose
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

Table 3-1d. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Cesium-137	1E-05	8E-08	>1E-02	>1E-02	3E-07	2E-09	1E-04	1E-04
Cobalt-60	7E-07	5E-08	7E-03	7E-03	1E-08	1E-09	4E-05	4E-05
Europium-152	1E-06	6E-07	>1E-02	>1E-02	3E-08	1E-08	3E-04	3E-04
Europium-154	3E-07	1E-07	9E-03	9E-03	7E-09	3E-09	6E-05	6E-05
Europium-155	2E-09	8E-10	6E-06	6E-06	5E-11	2E-11	4E-08	4E-08
Plutonium-238	8E-08	1E-07	2E-10	2E-07	2E-09	2E-09	1E-12	4E-09
Plutonium-239/240	2E-06	3E-06	4E-09	5E-06	4E-08	5E-08	3E-11	9E-08
Potassium-40[c]	2E-07	1E-09	2E-04	2E-04	4E-09	2E-11	1E-06	1E-06
Radium-226	1E-07	3E-08	1E-04	1E-04	2E-09	5E-10	7E-07	7E-07
Strontium-90	2E-06	2E-08	.b	2E-06	3E-08	5E-10	.b	3E-08
Thorium-228	7E-08	8E-07	1E-04	1E-04	1E-09	2E-08	8E-07	8E-07
Uranium-233/234	1E-08	2E-07	5E-10	2E-07	2E-10	3E-09	3E-12	3E-09
Uranium-238	2E-08	3E-07	5E-07	8E-07	4E-10	7E-09	3E-09	1E-10
Total	2E-05	5E-06	>1E-02	-	4E-07	1E-07	5E-04	-
High Priority Waste Site Total				>1E-02				5E-04

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

WHC-SD-EN-RA-004, Rev. 0

3T-1d

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-1e. Summary of the Risk Assessment for Radioactive Contaminants in 2018 at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Cesium-137	8E-06	5E-08	>1E-02	>1E-02
Cobalt-60	2E-08	2E-09	2E-04	2E-04
Europium-152	4E-07	2E-07	>1E-02	>1E-02
Europium-154	4E-08	2E-08	1E-03	1E-03
Europium-155	7E-11	2E-11	2E-07	2E-07
Plutonium-238	7E-08	1E-07	2E-10	2E-07
Plutonium-239/240	2E-06	3E-06	4E-09	5E-06
Potassium-40[c]	2E-07	1E-09	2E-04	2E-04
Radium-226	1E-07	3E-08	1E-04	1E-04
Strontium-90	9E-07	1E-08	_b	9E-07
Thorium-228	5E-12	7E-11	1E-08	1E-08
Uranium-233/234	1E-08	2E-07	4E-10	2E-07
Uranium-238	2E-08	3E-07	5E-07	8E-07
Total	1E-05	4E-06	>1E-02	-
High Priority Waste Site Total				>1E-02

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 3-1f. Summary of the Risk Assessment for Non-Radioactive Contaminants at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario						Occasional-Use Scenario					
	Pathway				Contaminant Totals		Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation				Soil Ingestion		Fugitive Dust Inhalation			
	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[d]	ICR[b]	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[d]	ICR[b]
Arsenic	2.0	1E-04	-[c]	3E-06	2	1E-04	0.03	2E-06	-[c]	7E-08	0.03	2E-06
Benzo(a)pyrene	-[c]	9E-06	-[c]	-[c]	-[c]	9E-06	-[c]	2E-07	-[c]	-[c]	-[c]	2E-07
Total	2.0	1E-04	-[c]	3E-06	-	-	0.03	2E-06	-[c]	7E-08	-	-
High Priority Waste Site Total					2	1E-04					0.03	2E-06

[a] Hazard quotient.
[b] Lifetime incremental cancer risk.
[c] No RfD or SF available to evaluate this pathway.
[d] Hazard index.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-1g. Estimated Dose for the Great Basin Pocket Mouse at the 116-H-1 Trench (0-15 ft).

Contaminant	Activity/ g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	400	9.9E-08	2.2E-02	0.51	1.1E-02
Cobalt-60	33	1.3E-08	5.1E-04	0.51	2.6E-04
Europium-152	530	2.1E-07	7.5E-06	0.51	3.8E-06
Europium-154	88	3.5E-08	2.5E-07	0.51	1.3E-07
Europium-155	4	1.6E-09	1.1E-08	0.51	5.5E-09
Plutonium-238	0.28	1.1E-10	1.3E-06	0.51	6.4E-07
Plutonium-239/240	6.6	2.6E-09	2.8E-05	0.51	1.4E-05
Radium-226	0.78	3.1E-10	2.0E-03	0.51	1.0E-03
Strontium-90	35	1.4E-08	2.9E+00	0.51	1.5E+00
Thorium-228	0.95	3.8E-10	1.0E-09	0.51	5.3E-10
Uranium-233/234	0.53	2.1E-10	5.5E-04	0.51	2.8E-04
Uranium-238	0.61	2.4E-10	5.6E-04	0.51	2.8E-04
Total Dose			2.96E+00		1.5E+00

Contaminant	Maximum Soil Concentration (mg/kg)	Concentration Vegetation (wet) (mg/kg)	Dose Rate (mg/kg/day)	Fractional Use	Dose Rate (mg/kg/day)
Arsenic	37.9	15	9.4E-01	0.51	4.8E-01
Benzo(a)pyrene	0.81	0.32	6.6E-03	0.51	3.4E-03

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-1h. Estimated Dose for the Great Basin Pocket Mouse at the
116-H-1 Trench (0-6 feet).

Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	400	9.94E-08	2.23E-02	0.51	1.14E-02
Cobalt-60	33	1.32E-08	5.10E-04	0.51	2.60E-04
Europium-152	530	2.12E-07	7.46E-06	0.51	3.80E-06
Europium-154	88	3.52E-08	2.53E-07	0.51	1.29E-07
Europium-155	4	1.60E-09	1.08E-08	0.51	5.51E-09
Plutonium-238	0.28	1.12E-10	1.25E-06	0.51	6.37E-07
Plutonium-239/240	6.6	2.64E-09	2.77E-05	0.51	1.41E-05
Strontium-90	35	1.40E-08	2.93E+00	0.51	1.50E+00
Total Dose					1.51E+00

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-2a. Historical and LFI Data Summary for the 116-H-2 Trench. (Sheet 1 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Cesium-134	0.082	2.06	0.00038	1	-	-	0.00038	6.0E-08	maximum concentration detected at or above 15 ft.
Cesium-137	77	30.2	53	5	-	-	53	29	maximum concentration detected at or above 15 ft.
Cobalt-60	6.4	5.2	0.75	1	-	-	0.75	0.026	maximum concentration detected at or above 15 ft.
Europium-152	27	13.6	12	1	-	-	12	3.2	maximum concentration detected at or above 15 ft.
Europium-154	6.2	8.8	1.8	1	-	-	1.8	0.23	maximum concentration detected at or above 15 ft.
Europium-155	2.5	4.9	0.26	1	-	-	0.26	0.0071	maximum concentration detected at or above 15 ft.
Plutonium-239/240	0.13	24,000	0.13	1	-	-	0.13	0.13	maximum concentration detected at or above 15 ft.
Potassium-40	-	1.3E+09	-	-	13	15	13	13	maximum concentration detected at or above 15 ft.
Radium-226	-	1,600	-	-	0.5	15	0.5	0.5	maximum concentration detected at or above 15 ft.
Strontium-90	73	28	49	1	-	-	49	26	maximum concentration detected at or above 15 ft.
Thorium-228	-	1.9	-	-	0.63	15	0.63	5.0E-05	maximum concentration detected at or above 15 ft.
Thorium-232	-	1.4E+10	-	-	0.35	10	0.35	0.35	maximum concentration detected at or above 15 ft.
Tritium	45	12.3	18	10	-	-	18	4.2	maximum concentration detected at or above 15 ft.
Uranium-238	-	4.5E+09	-	-	0.54	15	0.54	0.54	maximum concentration detected at or above 15 ft.
Total Uranium	0.45	4.5E+09	0.45	1	-	-	-	-	uranium-238 detected in LFI data exceeds historical total uranium concentration
Inorganics, mg/kg									
Aluminum	-	-	-	-	5,640	15	-[c]		eliminated based on HSBRAM[c]
Barium	-	-	-	-	69.9	15	-[d]		eliminated based on comparison to background[d]
Calcium	-	-	-	-	11,000	15	-[c]		eliminated based on HSBRAM[c]
Chromium	-	-	-	-	19	15	-[d]		eliminated based on comparison to background[d]
Cobalt	-	-	-	-	7.7	15	-[d]		eliminated based on comparison to background[d]
Copper	-	-	-	-	18.4	15	-[d]		eliminated based on comparison to background[d]
Iron	-	-	-	-	14,700	15	-[c]		eliminated based on HSBRAM[c]

Table 3-2a. Historical and LFI Data Summary for the 116-H-2 Trench. (Sheet 2 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data	
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Lead	-	-	-	-	4	15	.d	eliminated based on comparison to background[d]
Magnesium	-	-	-	-	4,720	15	.c	eliminated based on HSBRAM[c]
Manganese	-	-	-	-	246	15	.d	eliminated based on comparison to background[d]
Nickel	-	-	-	-	24.4	15	.d	eliminated based on comparison to background[d]
Potassium	-	-	-	-	916	15	.c	eliminated based on HSBRAM[c]
Vanadium	-	-	-	-	34.6	15	.d	eliminated based on comparison to background[d]
Zinc	-	-	-	-	35.7	15	.d	eliminated based on comparison to background[d]

- indicates parameter was not analyzed for or not reported.
[a]Dorian and Richards 1976 radiological data (1978).
[b]Depth indicated is the top of the sampling depth.
[c]Al, Ca, Fe, Mg, K and Na are eliminated from further consideration as recommended in HSBRAM (DOE-RL 1993a).
[d]Maximum concentration compared to contaminant specific 95% UTL on Table 2-1 and eliminated because it did not exceed background.

Table 3-2b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-2 Trench.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)^{-1}	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)^{-1}	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External·SF[a] (pCi-yr/g)^{-1}	Soil Concentration at External ICR = 1E-07 (pCi/g)
Cesium-134	0.00038	4.1E-11	1.9	2.8E-11	330	5.2E-06	0.00064
Cesium-137	53	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	0.75	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	12	2.1E-12	36	1.1E-10	83	3.6E-06	0.00093
Europium-154	1.8	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	0.26	4.5E-13	170	1.8E-11	510	5.9E-08	0.056
Plutonium 239/240	0.13	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120
Potassium 40	13	1.1E-11	6.9	7.6E-12	1,200	5.4E-07	0.0062
Radium-226	0.5	1.2E-10	0.63	3.0E-09	3	6.0E-06	0.00056
Strontium-90	49	3.6E-11	2.1	6.2E-11	150	.b	.b
Thorium-228	0.63	5.5E-11	1.4	7.8E-08	0.12	5.6E-06 .	0.0006
Thorium-232	0.35	1.2E-11	6.3	2.8E-08	0.33	2.6E-11	130
Tritium	18	5.4E-14	1,400	7.8E-14	1.2E+05	.b	.b
Uranium-238	0.54	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
[b]Not an external exposure hazard
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

WHC-SD-EN-RA-004, REV. 0

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-2c. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-2 Trench.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Cesium-137	2E-06	1E-08	3E-03	3E-03	4E-08	2E-10	2E-05	2E-05
Cobalt-60	1E-08	1E-09	2E-04	2E-04	3E-10	2E-11	1E-06	1E-06
Europium-152	3E-08	1E-08	1E-03	1E-03	6E-10	3E-10	7E-06	7E-06
Europium-154	7E-09	3E-09	2E-04	2E-04	1E-10	5E-11	1E-06	1E-06
Europium-155	2E-10	5E-11	4E-07	4E-07	3E-12	1E-12	2E-09	2E-09
Potassium-40[c]	2E-07	1E-09	2E-04	2E-04	4E-09	2E-11	1E-06	1E-06
Radium-226	8E-08	2E-08	7E-05	7E-05	2E-09	3E-10	5E-07	5E-07
Strontium-90	2E-06	3E-08	.b	2E-06	4E-08	6E-10	.b	4E-08
Thorium-228	5E-08	5E-07	8E-05	8E-05	9E-10	1E-08	5E-07	-5E-07
Thorium-232	6E-09	1E-07	2E-10	1E-07	1E-10	2E-09	1E-12	2E-09
Uranium-238	2E-08	3E-07	5E-07	8E-07	4E-10	6E-09	3E-09	9E-09
Total	4E-06	1E-06	5E-03	-	9E-08	2E-08	3E-05	-
High Priority Waste Site Total				5E-03				3E-05

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

3T-2c

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-2d. Summary of the Risk Assessment for Radioactive Contaminants in 2018
at the 116-H-2 Trench.

Contaminant	Frequent-Use Scenario			
	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Cesium-137	1E-06	6E-09	1E-03	1E-03
Cobalt-60	5E-10	4E-11	5E-06	5E-06
Europium-152	9E-09	4E-09	3E-04	3E-04
Europium-154	9E-10	3E-10	2E-05	2E-05
Europium-155	4E-12	1E-12	1E-08	1E-08
Potassium-40[c]	2E-07	1E-09	2E-04	2E-04
Radium-226	8E-08	2E-08	7E-05	7E-05
Strontium-90	1E-06	2E-08	_b	1E-06
Thorium-228	4E-12	4E-11	7E-09	7E-09
Thorium-232	5E-09	1E-07	2E-10	1E-07
Uranium-238	2E-08	3E-07	5E-07	8E-07
Total	2E-06	4E-07	2E-03	-
High Priority Waste Site Total				2E-03

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-2e. Estimated Dose for the Great Basin Pocket Mouse at the 116-H-2 Trench (0-15 ft).

Contaminant	Activity/ g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	53	1.3E-08	3.0E-02	1	3.0E-02
Cobalt-60	0.75	1.5E-10	1.2E-05	1	1.2E-05
Europium-152	12	4.8E-12	1.7E-07	1	1.7E-07
Europium-154	1.8	7.2E-13	5.2E-09	1	5.2E-09
Europium-155	0.26	1.0E-13	7.0E-10	1	7.0E-10
Plutonium-239/240	0.13	3.6E-12	0.54E-06	1	0.54E-06
Radium-226	0.5	2.0E-11	1.3E-03	1	1.3E-03
Strontium-90	49	3.7E-07	4.1E+00	1	4.1E+00
Thorium-232	0.35	1.4E-14	3.3E-10	1	4.1E+00
Uranium-238	0.45	2.2E-10	4.9E-04	1	4.9E-04
Total Dose					4.1E+00

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-2f. Estimated Dose for the Great Basin Pocket Mouse at the 116-H-2 Trench (0-6 feet.)

Contaminant	Activity/ g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	53	1.3E-08	3.0E-02	1	3.0E-02
Cobalt-60	0.75	1.5E-10	1.2E-05	1	1.2E-05
Europium-152	12	4.8E-12	1.7E-07	1	1.7E-07
Europium-154	1.8	7.2E-13	5.2E-09	1	5.2E-09
Europium-155	0.26	1.0E-13	7.0E-10	1	7.0E-10
Plutonium-239/240	0.13	3.6E-12	0.54E-06	1	0.54E-06
Strontium-90	49	3.7E-07	4.1E+00	1	4.1E+00
Total Dose					4.1E+00

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-3a. Historical and LFI Data Summary for the 116-H-3 French Drain. (Sheet 1 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Cesium-137	210[d]	30.2	150	4	-	-	150	80	maximum concentration detected at or above 15 ft.
Cobalt-60	110[d]	5.2	13	4	13	15	13	0.41	maximum concentration detected at or above 15 ft.
Europium-152	72[e]	13.6	32	4	0.54	15	32	8.5	maximum concentration detected at or above 15 ft.
Europium-154	17[e]	8.8	4.8	4	-	-	4.8	0.62	maximum concentration detected at or above 15 ft.
Europium-155	2.2	4.9	0.22	15	-	-	0.22	0.0062	maximum concentration detected at or above 15 ft.
Plutonium-239/240	0.27	24,000	0.27	15	-	-	0.27	0.27	maximum concentration detected at or above 15 ft.
Potassium-40	-	1.3E+09	-	-	9.8	15	9.8	9.8	maximum concentration detected at or above 15 ft.
Radium-226	-	1,600	-	-	(0.45)	(20)	-	-	not detected at or above 15 ft.
Strontium-90	0.56	28	0.38	15	-	-	0.38	0.20	maximum concentration detected at or above 15 ft.
Thorium-228	-	1.9	-	-	0.58	15	0.58	4.6E-05	maximum concentration detected at or above 15 ft.
Thorium-232	-	1.4E+10	-	-	0.44	15	0.44	0.44	maximum concentration detected at or above 15 ft.
Tritium	4.4	12.3	1.8	15	-	-	1.8	0.41	maximum concentration detected at or above 15 ft.
Uranium-233/234	-	2.4E+05	-	-	(0.35)	(20)	-	-	not detected at or above 15 ft.
Uranium-238	-	4.5E+09	-	-	0.58	15	0.58	0.58	maximum concentration detected at or above 15 ft.
Inorganics, mg/kg									
Aluminum	-	-	-	-	5,200	15	-[c]		eliminated based on HSBRAM[c]
Barium	-	-	-	-	42.5	15	-[f]		eliminated based on comparison to background[f]
Calcium	-	-	-	-	4,990	15	-[c]		eliminated based on HSBRAM[c]
Chromium	-	-	-	-	10.5	15	-[f]		eliminated based on comparison to background[f]
Cobalt	-	-	-	-	9.2	15	-[f]		eliminated based on comparison to background[f]

Table 3-3a. Historical and LFI Data Summary for the 116-H-3 French Drain. (Sheet 2 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data	
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Copper	-	-	-	-	12.9 (22.5)	15 (20)	_[f]	eliminated based on comparison to background[f]
Iron	-	-	-	-	15,900	15	_[c]	eliminated based on HSBRAM[c]
Lead	-	-	-	-	(8.6)	(20)	-	not detected at or above 15 ft.
Magnesium	-	-	-	-	3,690	15	-[c]	eliminated based on HSBRAM[c]
Manganese	-	-	-	-	231	15	_[f]	eliminated based on comparison to background[f]
Nickel	-	-	-	-	9.6	15	_[f]	eliminated based on comparison to background[f]
Potassium	-	-	-	-	739	15	_[c]	eliminated based on HSBRAM[c]
Vanadium	-	-	-	-	47.1	15	_[f]	eliminated based on comparison to background[f]
Zinc	-	-	-	-	39.1	15	_[f]	eliminated based on comparison to background[f]
Organics, µg/kg								
Diethylphthalate	-	-	-	-	(230)	(20)	-	not detected at or above 15 ft.

( ) indicates maximum concentration detected at depths greater than 15 ft.
- indicates parameter was not analyzed for or not reported.
[a]Dorian and Richards 1976 radiological data (1978).
[b]Depth indicated is the top of the sampling depth.
[c]Al, Ca, Fe, Mg, K and Na are eliminated from further consideration as recommended in HSBRAM (DOE-RL 1993a).
[d]Preliminary characterization samples taken in 1961. The results were decayed to 12/30/75. Samples were taken 2 1/2 ft away from the French drain.
[e]Samples were taken 4 ft away from the French drain.
[f]Maximum concentration compared to contaminant specific 95% UTL on Table 2-1 and eliminated because it did not exceed background.

Table 3-3b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-3 French Drain.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
Cesium-137	150	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	13	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	32	2.1E-12	36	1.1E-10	83	3.6E-06	0.00093
Europium-154	4.8	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	0.22	4.5E-13	170	1.8E-11	510	5.9E-08	0.056
Plutonium 239/240	0.27	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120
Potassium 40	9.8	1.1E-11	6.9	7.6E-12	1,200	5.4E-07	0.0062
Strontium-90	0.38	3.6E-11	2.1	6.2E-11	150	.b	.b
Thorium-228	0.58	5.5E-11	1.4	7.8E-08	0.12	5.6E-06	0.0006
Thorium-232	0.44	1.2E-11	6.3	2.8E-08	0.33	2.6E-11	130
Tritium	1.8	5.4E-14	1,400	7.8E-14	1.2E+05	.b	.b
Uranium-238	0.58	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992b)
[b]Not an external exposure hazard
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-3c. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-3 French Drain.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Cesium-137	5E-06	3E-08	7E-03	7E-03	1E-07	6E-10	4E-05	4E-05
Cobalt-60	3E-07	2E-08	3E-03	3E-03	5E-09	4E-10	2E-05	2E-05
Europium-152	9E-08	4E-08	3E-03	3E-03	2E-09	7E-10	2E-05	2E-05
Europium-154	2E-08	7E-09	5E-04	5E-04	4E-10	1E-10	3E-06	3E-06
Europium-155	1E-10	4E-11	3E-07	3E-07	2E-12	8E-13	2E-09	2E-09
Plutonium-239/240	8E-08	1E-07	2E-10	2E-07	2E-09	2E-09	1E-12	4E-09
Potassium-40[c]	1E-07	8E-10	1E-04	1E-04	3E-09	2E-11	8E-07	8E-07
Thorium-228	4E-08	5E-07	8E-05	8E-05	8E-10	1E-08	5E-07	5E-07
Thorium-232	7E-09	1E-07	3E-10	1E-07	1E-10	3E-09	2E-12	3E-09
Uranium-238	2E-08	3E-07	5E-07	8E-07	4E-10	6E-09	3E-09	9E-09
Total	6E-06	1E-06	>1E-02	-	1E-07	2E-08	8E-05	-
High Priority Waste Site Total				>1E-02				8E-05

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

3T-3c

WHC-SD-EN-RA-004, Rev. 0

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-3d. Summary of the Risk Assessment for Radioactive Contaminants in 2018
at the 116-H-3 French Drain.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Cesium-137	3E-06	2E-08	4E-03	4E-03
Cobalt-60	8E-09	7E-10	8E-05	8E-05
Europium-152	2E-08	1E-08	7E-04	7E-04
Europium-154	2E-09	1E-09	6E-05	6E-05
Europium-155	4E-12	1E-12	9E-09	9E-09
Plutonium-239/240	8E-08	1E-07	2E-10	2E-07
Potassium-40[c]	1E-07	8E-10	1E-04	1E-04
Thorium-228	3E-12	4E-11	6E-09	6E-09
Thorium-232	7E-09	1E-07	3E-10	1E-07
Uranium-238	2E-08	3E-07	5E-07	8E-07
Total	3E-06	5E-07	5E-03	-
High Priority Waste Site Total				5E-03

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-3e. Estimated Dose for the Great Basin Pocket Mouse at the
116-H-3 French Drain (0-15 ft).

Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	150	3.6E-08	8.1E-03	0.001	8.1E-06
Cobalt-60	13	2.60E-09	2.01E-04	0.001	2.01E-07
Europium-152	32	1.3E-11	4.5E-07	0.001	4.5E-10
Europium-154	4.8	1.9E-12	1.4E-08	0.001	1.4E-11
Europium-155	0.22	8.8E-14	5.9E-10	0.001	5.9E-13
Plutonium-239/240	0.27	7.6E-12	1.1E-06	0.001	1.1E-09
Strontium-90	0.38	2.89E-09	3.18E-02	0.001	3.18E-05
Thorium-228	0.58	2.3E-14	6.3E-10	0.001	6.3E-13
Thorium-232	0.44	1.8E-14	4.1E-10	0.001	4.1E-13
Uranium-238	0.58	2.3E-10	5.3E-04	0.001	5.4E-07
Total Dose		3.2E-01			3.2E-04

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-3f. Estimated Dose for the Great Basin Pocket Mouse at the
116-H-3 French Drain (0-6 feet)

Contaminant	Activity/g (pCi/g)	Activity/kg Vegetation (wet) (ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	150	3.7E-08	8.3E-03	0.001	8.3E-06
Europium-152	32	1.3E-11	4.5E-07	0.001	4.5E-10
Europium-154	5	1.9E-12	1.4E-08	0.001	1.4E-11
Total Dose					8.3E-06
Cobalt-60 was not calculated since concentration was <1/100 pCi/g.					

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4a. Historical and LFI Data Summary for the 116-H-7 Retention Basin. (Sheet 1 of 3)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Americium-241	-	432	-	-	0.72	10	0.72	0.69	maximum concentration detected at or above 15 ft.
Carbon-14	-	5,700	-	-	33 (34)	8 (20)	33	33	maximum concentration detected at or above 15 ft.
Cesium-134	1,200[d]	2.06	5.5[d]	3	-	-	5.5	0.00087	maximum concentration detected at or above 15 ft.
Cesium-137	2,900[d]	30.2	2000[d]	4	35	10	2,000	1,100	maximum concentration detected at or above 15 ft.
Cobalt-60	18,000[d]	5.27	2200[d]	5	36	10	2,200	72	maximum concentration detected at or above 15 ft.
Europium-152	39,000[d]	13.6	17,000[d]	5	260	10	17,000	4,600	maximum concentration detected at or above 15 ft.
Europium-154	20,000[d]	8.8	5,700[d]	5	37	10	5,700	730	maximum concentration detected at or above 15 ft.
Europium-155	6,200[d]	4.96	660[d]	4	-	-	660	19	maximum concentration detected at or above 15 ft.
Nickel-63	20,000[d]	100	18,000[d]	5	-	-	18,000	15,000	maximum concentration detected at or above 15 ft.
Plutonium-238	7.7[d]	87.8	6.8[d]	4	-	-	6.8	5.5	maximum concentration detected at or above 15 ft.
Plutonium-239/240	200[d]	24,000	200[d]	4	1.3	10	200	200	maximum concentration detected at or above 15 ft.
Potassium-40	-	1.3E+09	-	-	33	10	33	33	maximum concentration detected at or above 15 ft.
Radium-226	-	1,600	-	-	0.65	15	0.65	0.64	maximum concentration detected at or above 15 ft.
Strontium-90	350[d]	28.6	240[d]	4	3.2	8	240	130	maximum concentration detected at or above 15 ft.
Technetium-99	-	2.1E+05	-	-	0.26	15	0.26	0.26	maximum concentration detected at or above 15 ft.
Thorium-228	-	1.9	-	-	0.81	15	0.81	6.5E-05	maximum concentration detected at or above 15 ft.
Thorium-232	-	1.4E+10	-	-	0.41 (0.44)	1 (20)	0.41	0.41	maximum concentration detected at or above 15 ft.
Tritium	370[d]	12.3	150[d]	4	-	-	150	35	maximum concentration detected at or above 15 ft.
Uranium-235	-	7.8E+08	-	-	0.38	10	-	-	total uranium from historical data used
Uranium-238	-	4.5E+09	-	-	0.69	1	-	-	maximum concentration detected at or above 15 ft.

Table 3-4a. Historical and LFI Data Summary for the 116-H-7 Retention Basin. (Sheet 2 of 3)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
			Decayed to 1992				1992	2018	
Total Uranium[f]	4.7[d]	4.5E+09	4.7[d]	5	-	-	4.7	4.7	maximum concentration detected at or above 15 ft.
Zirconium-95	-	64	-	-	0.56	1	0.56	1.1E-45	maximum concentration detected at or above 15 ft.
Inorganics, mg/kg									
Aluminum	-	-	-	-	9,070	1	-c		eliminated based on HSBRAM[c]
Arsenic	-	-	-	-	47	1	47		concentration detected at or above 15 ft.
Barium	-	-	-	-	94	1	-e		eliminated based on comparison to background[e]
Calcium	-	-	-	-	8,620	8	-c		eliminated based on HSBRAM[c]
Chromium	-	-	-	-	28.3	10	28.3		maximum concentration detected at or above 15 ft.
Cobalt	-	-	-	-	9.2	1	-e		eliminated based on comparison to background[e]
Copper	-	-	-	-	23.4	10	-e		eliminated based on comparison to background[e]
Iron	-	-	-	-	19,000	1	-c		eliminated based on HSBRAM[c]
Lead	-	-	-	-	540	1	540		maximum concentration detected at or above 15 ft.
Magnesium	-	-	-	-	4,630	1	-c		eliminated based on HSBRAM[c]
Manganese	-	-	-	-	325	1	-e		eliminated based on comparison to background[e]
Mercury	-	-	-	-	1.1	10	-e		eliminated based on comparison to background[e]
Nickel	-	-	-	-	12.7	15	-e		eliminated based on comparison to background[e]
Potassium	-	-	-	-	1,720	1	-c		eliminated based on HSBRAM[c]
Vanadium	-	-	-	-	40	1	-e		eliminated based on comparison to background[e]
Zinc	-	-	-	-	83.1	10	83.1		maximum concentration detected at or above 15 ft.

Table 3-4a. Historical and LFI Data Summary for the 116-H-7 Retention Basin. (Sheet 3 of 3)

Parameter	Historical Data[a]				LFI Data		QRA Data	
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Organics, µg/kg								
Toluene	-	-	-	-	49	8	49	maximum concentration detected at or above 15 ft.

( ) indicates maximum concentration detected at depths greater than 15 ft.
- indicates parameter was not analyzed for or not reported.
[a]Dorian and Richards 1976 radiological data (1978).
[b]Depth indicated is the top of the sampling depth.
[c]Al, Ca, Fe, Mg, K and Na are eliminated from further consideration as recommended in HSBRAM (DOE-RL 1993a). .
[d]Historical data were taken from basin fill sludge samples.
[e]Maximum concentration compared to contaminant specific 95% UTL on Table 2-1 and eliminated because it did not exceed background.
[f]Uranium isotope is not specified. Assumed to be uranium-238 (see Chapter 2).

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-7 Retention Basin.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)^-1	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)^-1	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)^-1	Soil Concentration at External ICR = 1E-07 (pCi/g)
Americium-241	0.72	2.4E-10	0.32	3.2E-08	0.29	4.9E-09	0.68
Carbon-14	33	9.0E-13	85	6.4E-15	1.4E+06	.b	.b
Cesium-134	5.5	4.1E-11	1.9	2.8E-11	330	5.2E-06	0.00064
Cesium-137	2,000	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	2,200	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	17,000	2.1E-12	36	1.1E-10	83	3.6E-06	0.00093
Europium-154	5,700	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	660	4.5E-13	170	1.8E-11	510	5.9E-06	0.056
Nickel-63	18,000	2.4E-13	320	1.8E-12	5,100	.b	.b
Plutonium-238	6.8	2.2E-10	0.35	3.9E-08	0.23	2.8E-11	120
Plutonium 239/240	200	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120
Potassium 40	33	1.1E-11	6.9	7.6E-12	1,200	5.4E-07	0.0062
Radium-226	0.65	1.2E-10	0.63	3.0E-09	3	6.0E-06	0.00056
Strontium-90	240	3.6E-11	2.1	6.2E-11	150	.b	.b
Technetium-99	0.26	1.3E-12	59	8.3E-12	1,100	6.0E-13	5,600
Thorium-228	0.81	5.5E-11	1.4	7.8E-08	0.12	5.6E-06	0.0006
Thorium-232	0.41	1.2E-11	6.3	2.8E-08	0.33	2.6E-11	130
Tritium	150	5.4E-14	1,400	7.8E-14	1.2E+05	.b	.b
Uranium-238	4.7	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093
Zirconium-95	0.56	9.9E-13	77	1.0E-11	910	2.5E-06	0.0013

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
[b]Not an external exposure hazard
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

WHC-SD-EN-RA-004, Rev. 0

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4c. Preliminary Risk-Based Screening for Non-Radioactive Soil Contaminants at the 116-H-7 Retention Basin.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at Oral HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at Inhalation HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF (mg/kg-d)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
INORGANICS										
Arsenic	47	3.0E-04[a]	2.4	.c	.c	1.7E+00[a,f]	0.038	5.0E+01[a,g]	1.18	-
Chromium[j]	28.3	5.0E-03[a]	40	.c	.c	.d	.d	4.1E+01[a]	0.4	-
Lead	540	.c	.c	.c	.c	.c	.c	.c	.c	500-1000[e]
Zinc	83.1	3.0E-01[a]	2,400	.c	.c	.d	.d	.d	.d	-
ORGANICS										
Toluene	0.049	2.0E-01[a]	1,600	1.1E-01[b,i]	1.8E+01	.d	.d	.d	.d	-

[a]Integrated Risk Information System (IRIS, EPA 1993).
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992).
[c]No RfD or SF available to evaluate this pathway.
[d]Not classified as a carcinogen or not carcinogenic via this exposure route or pathway.
[e]EPA 1989.
[f]Based on proposed arsenic unit risk of 5E-05 μg/L (IRIS, EPA 1993).
[g]Based on 30% absorption of inhaled arsenic.
[i]Based on calculation for inhalation of volatiles.
[j]Chromium evaluated as Chromium VI.
- Not applicable.
HQ = Hazard quotient.
ICR = Lifetime incremental cancer risk.
RfD = Chronic reference dose.
SF = Slope factor.
Note: Shaded area indicates screening criterion exceeded.

3T-4c

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-4d. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Americium-241	2E-07	3E-07	8E-08	5E-07	4E-09	5E-09	5E-10	1E-08
Cesium-134	3E-07	2E-09	7E-04	7E-04	6E-09	3E-11	4E-06	4E-06
Cesium-137	7E-05	4E-07	>1E-02	>1E-02	1E-06	8E-09	6E-04	6E-04
Cobalt-60	4E-05	4E-06	>1E-02	>1E-02	8E-07	7E-08	3E-03	3E-03
Europium-152	5E-05	2E-05	>1E-02	>1E-02	9E-07	4E-07	9E-03	9E-03
Europium-154	2E-05	9E-06	>1E-02	>1E-02	4E-07	2E-07	3E-03	3E-03
Europium-155	4E-07	1E-07	9E-04	9E-04	7E-09	3E-09	6E-06	6E-06
Nickel-63	6E-06	4E-07	.b	6E-06	1E-07	7E-09	.b	1E-07
Plutonium-238	2E-06	3E-06	5E-09	5E-06	4E-08	6E-08	3E-11	1E-07
Plutonium-239/240	6E-05	8E-05	1E-07	1E-04	1E-06	2E-06	8E-10	3E-06
Potassium-40[c]	5E-07	3E-09	4E-04	4E-04	9E-09	5E-11	3E-06	3E-06
Radium-226	1E-07	2E-08	9E-05	9E-05	2E-09	4E-10	6E-07	6E-07
Strontium-90	1E-05	2E-07	.b	1E-05	2E-07	3E-09	.b	2E-07
Thorium-228	6E-08	7E-07	1E-04	1E-04	1E-09	1E-08	7E-07	7E-07
Thorium-232	6E-09	1E-07	3E-10	1E-07	1E-10	2E-09	2E-12	2E-09
Uranium-238	2E-07	3E-06	4E-06	7E-06	3E-09	5E-08	3E-08	8E-08
Zirconium-95	7E-10	6E-11	3E-05	3E-05	1E-11	1E-12	2E-07	2E-07
Total	3E-04	1E-04	>1E-02	-	4E-06	3E-06	>1E-02	-
High Priority Waste Site Total				>1E-02				>1E-02

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4e. Summary of the Risk Assessment for Radioactive Contaminants in 2018 at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Americium-241	2E-07	2E-07	8E-08	5E-07
Cesium-134	5E-11	3E-13	1E-07	1E-07
Cesium-137	4E-05	2E-07	>1E-02	>1E-02
Cobalt-60	1E-06	1E-07	>1E-02	>1E-02
Europium-152	1E-05	6E-06	>1E-02	>1E-02
Europium-154	3E-06	1E-06	>1E-02	>1E-02
Europium-155	1E-08	3E-09	2E-05	2E-05
Nickel-63	5E-06	3E-07	_b	5E-06
Plutonium-238	2E-06	2E-06	4E-09	4E-06
Plutonium-239/240	6E-05	8E-05	1E-07	1E-04
Potassium-40[c]	5E-07	3E-09	4E-04	4E-04
Radium-226	1E-07	2E-08	9E-05	9E-05
Strontium-90	6E-06	9E-08	_b	6E-06
Thorium-228	5E-12	6E-11	9E-09	9E-09
Thorium-232	6E-09	1E-07	3E-10	1E-07
Uranium-238	2E-07	3E-06	4E-06	7E-06
Zirconium-95	1E-52	1E-55	6E-50	6E-50
Total	9E-05	9E-05	>1E-02	-
High Priority Waste Site Total				>1E-02

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-4f. Summary of the Risk Assessment for Non-Radioactive Contaminants at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario						Occasional-Use Scenario					
	Pathway				Contaminant Totals		Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation				Soil Ingestion		Fugitive Dust Inhalation			
	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[e]	ICR[b]	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[e]	ICR[b]
Arsenic	2	1E-04	-c	1E-05	2	1E-04	0.04	2E-06	-c	3E-07	0.04	2E-06
Chromium VI	0.07	-d	-c	7E-06	0.07	7E-06	0.001	-d	-c	1E-07	0.001	1E-07
Total	2	1E-04	-c	2E-05	-	-	0.04	2E-06	-c	4E-07	-	-
High Priority Waste Site Total					2	1E-04					0.04	2E-06

a Hazard quotient.
b Lifetime incremental cancer risk.
c No RfD or SF available to evaluate this pathway.
d Not classified as a carcinogen or not carcinogenic via this exposure route or pathway.
e Hazard index.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4g. Estimated Dose for the Great Basin Pocket Mouse at the
116-H-7 Retention Basin (0-15 ft).

Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Americium-241	0.72	2.9E-12	4.6E-07	1	4.6E-07
Carbon-14	33	7.3E-08	4.2E-03	1	4.2E-03
Cesium-134	5.5	5.5E-10	1.2E-04	1	1.2E-04
Cesium-137	2000	5.0E-07	1.1E-01	1	1.1E-01
Cobalt-60	2200	4.4E-07	3.4E-02	1	3.4E-02
Europium-152	17,000	6.8E-09	2.4E-04	1	2.4E-04
Europium-154	5700	2.3E-10	1.6E-05	1	1.6E-05
Europium-155	660	2.6E-10	1.8E-06	1	1.8E-06
Nickel-63	18,000	7.2E-07	1.5E-02	1	1.5E-02
Plutonium-238	7	2.0E-10	3.1E-05	1	3.1E-05
Plutonium-239/240	200	5.6E-09	8.4E-04	1	8.4E-04
Radium-226	0.65	2.6E-11	1.6E-03	1	1.6E-03
Strontium-90	240	1.8E-06	2.0E+01	1	2.0E+01
Technetium-99	0.26	2.00E-09	2.2E-02	1	2.2E-02
Thorium-228	0.81	3.2E-14	8.8E-10	1	8.8E-10
Thorium-232	0.41	1.6E-14	3.8E-10	1	3.8E-10
Tritium	150	2.9E-07	1.9E-04	1	1.9E-04
Uranium-238	4.7	1.9E-09	4.3E-03	1	4.4E-03
Zirconium-95	0.56	1.12E-12	9.03E-08	1	9.0E-08
Total Dose			2.0E+01		2.0E+01
Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Arsenic	47	0.752	1.2E+00	1	1.2E+00
Chromium VI	28.3	0.0849	1.3E-01	1	1.3E-01
Lead	540	9.72	1.5E+01	1	1.5E+01
Zinc	83	49.8	7.8E+01	1	7.8E+01

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-4h. Estimated Dose for the Great Basin Pocket Mouse at the
116-H-7 Retention Basin (0-6 feet).

Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Americium-241	0.72	2.9E-12	4.6E-07	1	4.6E-07
Carbon-14	33	7.3E-08	4.2E-03	1	4.2E-03
Cesium-134	5.5	5.5E-10	1.2E-04	1	1.2E-04
Cesium-137	2000	5.0E-07	1.1E-01	1	1.1E-01
Cobalt-60	2200	4.4E-07	3.4E-02	1	3.4E-02
Europium-152	17,000	6.8E-09	2.4E-04	1	2.4E-04
Europium-154	5700	2.3E-10	1.6E-05	1	1.6E-05
Europium-155	660	2.6E-10	1.8E-06	1	1.8E-06
Nickel-63	18,000	7.2E-07	1.5E-02	1	1.5E-02
Plutonium-238	7	2.0E-10	3.1E-05	1	3.1E-05
Plutonium-239/240	200	5.6E-09	8.4E-04	1	8.4E-04
Radium-226	0.65	2.6E-11	1.6E-03	1	1.6E-03
Strontium-90	240	1.8E-06	2.0E+01	1	2.0E+01
Technetium-99	0.26	2.00E-09	2.2E-02	1	2.2E-02
Thorium-228	0.81	3.2E-14	8.8E-10	1	8.8E-10
Thorium-232	0.41	1.6E-14	3.8E-10	1	3.8E-10
Tritium	150	2.9E-07	1.9E-04	1	1.9E-04
Uranium-238	4.7	1.9E-09	4.3E-03	1	4.4E-03
Zirconium-95	0.56	1.12E-12	9.03E-08	1	9.0E-08
Total Dose			2.0E+01		2.0E+01
Contaminant	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Arsenic	47	0.752	1.2E+00	1	1.2E+00
Chromium VI	28.3	0.0849	1.3E-01	1	1.3E-01
Lead	540	9.72	1.5E+01	1	1.5E+01
Zinc	83	49.8	7.8E+01	1	7.8E+01

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-5a. Historical and LFI Data Summary for the 116-H-9 Crib. (Sheet 1 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Cesium-137	-	30.2	-	-	(0.29)	(18)	-	-	not detected at or above 15 ft.
Potassium-40	-	1.3E+09	-	-	15	3	15	15	maximum concentration detected at or above 15 ft.
Radium-226	-	1,600	-	-	0.64 (0.71)	3 (18)	0.64	0.63	maximum concentration detected at or above 15 ft.
Thorium-228	-	1.9	-	-	1.2	3	1.2	9.6E-05	maximum concentration detected at or above 15 ft.
Thorium-232	-	1.4E+10	-	-	0.75 (1.10)	3 (18)	0.75	0.75	maximum concentration detected at or above 15 ft.
Uranium-238	-	4.5E+09	-	-	0.47	3	0.47	0.47	maximum concentration detected at or above 15 ft.
Inorganics, mg/kg									
Aluminum	-	-	-	-	74,400	3	.[c]		eliminated based on HSBRAM[c]
Barium	-	-	-	-	672	3	672		maximum concentration detected at or above 15 ft.
Beryllium	-	-	-	-	4.7	3	4.7		maximum concentration detected at or above 15 ft.
Calcium	-	-	-	-	79,000	3	.[c]		eliminated based on HSBRAM[c]
Chromium	-	-	-	-	114	3	114		maximum concentration detected at or above 15 ft.
Cobalt	-	-	-	-	86.4	3	86.4		maximum concentration detected at or above 15 ft.
Copper	-	-	-	-	195	3	195		maximum concentration detected at or above 15 ft.
Iron	-	-	-	-	184,000	3	.[c]		eliminated based on HSBRAM[c]
Lead	-	-	-	-	7.9	3	.[d]		eliminated based on comparison to background[d]
Magnesium	-	-	-	-	50,000	3	.[c]		eliminated based on HSBRAM[c]
Manganese	-	-	-	-	3,050	3	3,050		maximum concentration detected at or above 15 ft.
Nickel	-	-	-	-	132	3	132		maximum concentration detected at or above 15 ft.

Table 3-5a. Historical and LFI Data Summary for the 116-H-9 Crib. (Sheet 2 of 2)

Parameter	Historical Data[a]				LFI Data		QRA Data	
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.[b])	Concentration Used in QRA	Rationale for Selection
Potassium	-	-	-	-	13,000	3	-[c]	eliminated based on HSBRAM[c]
Sodium	-	-	-	-	2,010	3	-[c]	eliminated based on HSBRAM[c]
Vanadium	-	-	-	-	389	3	389	maximum concentration detected at or above 15 ft.
Zinc	-	-	-	-	430	3	430	maximum concentration detected at or above 15 ft.

( ) indicates maximum concentration detected at depths greater than 15 ft.
- indicates parameter was not analyzed for or not reported.
[a]Dorian and Richards 1976 radiological data (1978).
[b]Depth indicated is the top of the sampling depth.
[c]Al, Ca, Fe, Mg, K and Na are eliminated from further consideration as recommended in HSBRAM (DOE-RL 1993b).
[d]Maximum concentration compared to contaminant specific 95% UTL on Table 2-1 and eliminated because it did not exceed background.

Table 3-5b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-9 Crib.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
Potassium 40	15	1.1E-11	6.9	7.6E-12	1,200	5.4E-07	0.062
Radium-226	0.64	1.2E-10	0.63	3.0E-09	3	6.0E-06	0.00056
Thorium-228	1.2	5.5E-11	1.4	7.8E-08	0.12	5.6E-06	0.0006
Thorium-232	0.75	1.2E-11	6.3	2.8E-08	0.33	2.6E-11	130
Uranium-238	0.47	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-5c. Preliminary Risk-Based Screening for Non-Radioactive Soil Contaminants at the 116-H-9 Crib.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg-d)	Soil Concentration at Oral HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Soil Concentration at Inhalation HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (mg/kg)	Inhalation SF (mg/kg-d)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
INORGANICS										
Barium	672	7.0E-02[a]	560	1.0E-04[b]	320	.e	.e	.e	.e	-
Beryllium	4.7	5.0E-03[a]	40	.d	.d	4.3E+00[a]	0.015	8.4E+00[a]	1.9	-
Chromium[g]	114	5.0E-03[a]	40	.d	.d	.e	.e	4.1E+01	0.4	-
Cobalt	86.4	6.0E-02[c]	480	.d	.d	.e	.e	.e	.e	-
Copper	195	4.0E-02[c]	320	.d	.d	.e	.e	.e	.e	-
Manganese	3,050	1.4E-01[a]	1,100	1.1E-04[a]	350	.e	.e	.e	.e	-
Nickel	132	2.0E-02[a]	160	.d	.d	.e	.e	.f	.f	-
Vanadium	389	7.0E-03[b]	56	.d	.d	.e	.e	.e	.e	-
Zinc	430	3.0E-01[a]	2,400	.d	.d	.e	.e	.e	.e	-

[a]Integrated Risk Information System (IRIS, EPA 1993).
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992).
[c]Superfund Technical Support Center.
[d]No RfD or SF available to evaluate this pathway.
[e]Not classified as a carcinogen or not carcinogenic via this exposure route or pathway
[f]Nickel is not evaluated because it is not present as refinery dust -- see Appendix B.
[g]Chromium evaluated as Chromium VI.
- Not applicable
HQ = Hazard quotient
ICR = Lifetime incremental cancer risk
RfD = Chronic reference dose
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-5d. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Potassium-40[b]	2E-07	1E-09	2E-04	2E-04	4E-09	2E-11	1E-06	1E-06
Radium-226	1E-07	2E-08	9E-05	9E-05	2E-09	4E-10	6E-07	6E-07
Thorium-228	9E-08	1E-06	2E-04	2E-04	2E-09	2E-08	1E-06	1E-06
Thorium-232	1E-08	2E-07	5E-10	2E-07	2E-10	4E-09	3E-12	4E-09
Uranium-238	2E-08	3E-07	4E-07	7E-07	3E-10	5E-09	3E-09	8E-09
Total	4E-07	2E-06	5E-04	-	9E-09	3E-08	3E-06	-
High Priority Waste Site Total				5E-04				3E-06

[a]Lifetime incremental cancer risk.
[b]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

3T-5d

WHC-SD-EN-RA-004, Rev. 0

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-5e. Summary of the Risk Assessment for Radioactive Contaminants in 2018
at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Potassium-40[b]	2E-07	1E-09	2E-04	2E-04
Radium-226	1E-07	2E-08	9E-05	9E-05
Thorium-228	7E-12	8E-11	1E-08	1E-08
Thorium-232	1E-08	2E-07	5E-10	2E-07
Uranium-238	2E-08	3E-07	4E-07	7E-07
Total	3E-07	5E-07	3E-04	-
High Priority Waste Site Total				3E-04

[a]Lifetime incremental cancer risk.
[b]Not of anthropogenic origin.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-5f. Summary of the Risk Assessment for Non-Radioactive Contaminants at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario						Occasional-Use Scenario					
	Pathway				Contaminant Totals		Pathway				Contaminant Totals	
	Soil Ingestion		Fugitive Dust Inhalation				Soil Ingestion		Fugitive Dust Inhalation			
	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[e]	ICR[b]	HQ[a]	ICR[b]	HQ[a]	ICR[b]	HI[e]	ICR[b]
Barium	0.1	-d	0.2	-d	0.3	-d	0.03	-d	0.004	-d	0.03	-d
Beryllium	0.01	3E-05	-c	2E-07	0.01	3E-05	0.0002	6E-07	-c	5E-09	0.0002	6E-07
Chromium VI	0.3	-d	-c	3E-05	0.3	3E-05	0.005	-d	-c	5E-07	0.005	5E-07
Manganese	0.3	-d	0.9	-d	1.2	-d	0.14	-d	0.02	-d	0.16	-d
Vanadium	0.7	-d	-c	-d	0.7	-d	0.01	-d	-c	-d	0.01	-d
Total	1.4	3E-05	1.1	3E-05	-	-	0.19	6E-07	0.02	5E-07	-	-
High Priority Waste Site Total					2.5	6E-05					0.21	1E-06

[a] Hazard quotient.
[b] Lifetime incremental cancer risk.
[c] No RfD or SF available to evaluate this pathway.
[d] Not classified as a carcinogen or not carcinogenic via this exposure route or pathway.
[e] Hazard index.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-5g. Estimated Dose for the Great Basin Pocket Mouse at the 116-H-9 Crib (0-15 ft).

Contaminant	Activity/g (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Radium-226	0.64	2.6E-11	1.6E-03	0.14	2.2E-04
Thorium-228	1.2	4.8E-14	1.3E-09	0.14	1.8E-10
Thorium-232	0.75	3E-14	7.0E-10	0.14	9.8E-11
Uranium-238	0.47	1.9E-10	4.3E-04	0.14	6.0E-05
Total Dose			2.04E-03		2.3E-04

Contaminant	Maximum Soil Concentration	Concentration in Vegetation (wet)	Dose Rate (mg/day/kg)	Fractional Use	Dose Rate (mg/day/kg)
Barium	672	4.03E+01	6.28E+01	0.14	8.79E+00
Beryllium	4.7	1.88E-02	2.93E-02	0.14	4.10E-03
Chromium VI	114	3.42E-01	5.33E-01	0.14	7.46E-02
Manganese	3050	3.05e+02	4.75E+02	0.14	6.65E+01
Vanadium	389	8.56E-01	1.33E+00	0.14	1.87E-01

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-5h. Estimated Dose for the Great Basin Pocket Mouse
at the 116-H-9 Crib (0-6 feet).

Contaminant	Activity/g (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Radium-226	0.64	2.6E-11	1.6E-03	0.14	2.2E-04
Thorium-228	1.2	4.8E-14	1.3E-09	0.14	1.8E-10
Uranium-238	0.47	1.9E-10	4.3E-04	0.14	6.0E-05
Total Dose			2.04E-03		2.3E-04

Contaminant	Maximum Soil Concentration	Concentration in Vegetation (wet)	Dose Rate (mg/day/kg)	Fractional Use	Dose Rate (mg/day/kg)
Barium	672	4.03E+01	6.28E+01	0.14	8.79E+00
Beryllium	4.7	1.88E-02	2.93E-02	0.14	4.10E-03
Chromium VI	114	3.42E-01	5.33E-01	0.14	7.46E-02
Manganese	3050	3.05e+02	4.75E+02	0.14	6.65E+01
Vanadium	389	8.56E-01	1.33E+00	0.14	1.87E-01

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-6a. Historical and LFI Data Summary for the Process Effluent Pipelines. (Sheet 1 of 2)

Parameter	Historical Data				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.)	Concentration Used in QRA		Rationale for Selection
SOIL COLUMN ALONG PIPELINE									
Radionuclides pCi/g			Decayed to 1992				1992	2018	
Cesium-137	0.049[b]	30.2	0.034	.c	.	.	0.034	0.019	maximum concentration detected at or above 15 ft.
Cobalt-60	0.31[b]	5.27	0.038	.c	.	.	0.038	0.0012	maximum concentration detected at or above 15 ft.
Europium-152	0.25[b]	13.6	0.11	.c	.	.	0.11	0.029	maximum concentration detected at or above 15 ft.
Europium-154	0.28[a]	8.8	0.079	.c	.	.	0.079	0.010	maximum concentration detected at or above 15 ft.
Europium-155	0.36[b]	4.96	0.039	.c	.	.	0.039	0.0010	maximum concentration detected at or above 15 ft.
Plutonium-238	0.027[a]	87.8	0.024	.c	.	.	0.024	0.019	maximum concentration detected at or above 15 ft.
Plutonium-239/240	0.14[a]	2.4E+04	0.14	.c	.	.	0.14	0.14	maximum concentration detected at or above 15 ft.
Strontium-90	0.13[a]	28.6	0.088	.c	.	.	0.088	0.047	maximum concentration detected at or above 15 ft.
Tritium	43[b]	12.3	18	.c	.	.	18	4.0	maximum concentration detected at or above 15 ft.
Uranium[f]	0.3[b]	4.5E+09	0.3	.c	.	.	0.3	0.3	maximum concentration detected at or above 15 ft.
INLET DISTRIBUTION BOX AND BASIN FILL SLUDGE									
Cesium-134	1,200[d]	2.06	5.5	38	.	.	5.5	0.00087	maximum concentration detected at or above 15 ft.
Cesium-137	4,200[e]	30.2	2,900	28	.	.	2,900	1,600	maximum concentration detected at or above 15 ft.
Cobalt-60	93,000[e]	5.27	11,000	28	.	.	11,000	370	maximum concentration detected at or above 15 ft.
Europium-152	59,000[e]	13.6	26,000	28	.	.	26,000	6,900	maximum concentration detected at or above 15 ft.
Europium-154	20,000[d]	8.8	5,700	58	.	.	5,700	730	maximum concentration detected at or above 15 ft.
Europium-155	6,200[d]	4.96	660	48	.	.	660	18	maximum concentration detected at or above 15 ft.
Nickel-63	20,000[d]	100	18,000	58	.	.	18,000	15,000	maximum concentration detected at or above 15 ft.

Table 3-6a. Historical and LFI Data Summary for the Process Effluent Pipelines. (Sheet 2 of 2)

Parameter	Historical Data				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.)	Concentration Used in QRA		Rationale for Selection
Radionuclides pCi/g			Decayed to 1992				1992	2018	
Plutonium-238	11[e]	87.8	9.7	2[g]	-	-	9.7	7.9	maximum concentration detected at or above 15 ft.
Plutonium-239/240	230[e]	2.4E+04	230	2[g]	-	-	230	230	maximum concentration detected at or above 15 ft.
Strontium-90	1,400[e]	28.6	950	2[g]	-	-	950	510	maximum concentration detected at or above 15 ft.
Tritium	1,600[e]	12.3	650	2[g]	-	-	650	150	maximum concentration detected at or above 15 ft.
Uranium[f]	4.7[d]	4.4E+09	4.7	5[g]	-	-	4.7	4.7	maximum concentration detected at or above 15 ft.

- indicates parameter was not analyzed for or not reported.

[a]Sample taken in 1976 from soil column along effluent lines from 116-H-7 basin to outfall structure (Dorian and Richards 1978).

[b]Sample taken in 1976 from soil column along effluent lines to 116-H-7 basin (Dorian and Richards 1978).

[c]Depth of samples is not available, it is assumed that the sample came from soil above 15 ft.

[d]Sample concentration is from 1976 basin fill sludge data (Dorian and Richards 1978).

[e]Sample concentration is from 1976 inlet distribution box sludge data (Dorian and Richards 1978).

[f]Uranium isotope is not specified. Assumed to be uranium-238 (see Chapter 2).

[g]Actual depth of process effluent pipelines is approximately 6m (20 ft.).

Table 3-6b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the Process Effluent Pipelines.
(Sheet 1 of 2)

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
SOIL							
Cesium-137	0.034	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	0.038	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	0.11	2.1E-12	36	1.1E-10	83 ·	3.6E-06	0.00093
Europium-154	0.079	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	0.039	4.5E-13	170	1.8E-11	510	5.9E-08	0.056
Plutonium-238	0.024	2.2E-10	0.35	3.9E-08	0.23	2.8E-11	120
Plutonium 239/240	0.14	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120
Strontium-90	0.088	3.6E-11	2.1	6.2E-11	150	_b	_b
Tritium	18	5.4E-14	1,400	7.8E-14	1.2E+05	_b	_b
Uranium[c]	0.3	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093
SLUDGE							
Cesium-134	5.5	4.1E-11	1.9	2.8E-11	330	5.2E-06	0.00064
Cesium-137	2,900	2.8E-11	2.7	1.9E-11	480	2.0E-06	0.0017
Cobalt-60	11,000	1.5E-11	5.1	1.5E-10	61	8.6E-06	0.00039
Europium-152	26,000	2.1E-12	36	1.1E-10	83	3.6E-06	0.00093
Europium-154	5,700	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	660	4.5E-13	170	1.8E-11	510	5.9E-08	0.056
Nickel-63	18,000	2.4E-13	320	1.8E-12	5,100	_b	_b
Plutonium-238	9.7	2.2E-10	0.35	3.9E-08	0.23	2.8E-11	120
Plutonium 239/240	230	2.3E-10	0.33	3.8E-08	0.24	2.7E-11	120

Table 3-6b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the Process Effluent Pipelines.
(Sheet 2 of 2)

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
Strontium-90	950	3.6E-11	2.1	6.2E-11	150	.b	.b
Tritium	650	5.4E-14	1,400	7.8E-14	1.2E+05	.b	.b
Uranium[c]	4.7	2.8E-11	2.7	5.2E-08	0.18	3.6E-08	0.093

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
[b]Not an external exposure hazard
[c]Assumed to be uranium-238 (see Chapter 2).
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

WHC-SD-EN-RA-004, Rev. 0

3T-6c-a

Table 3-6c. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the Process Effluent Pipeline. (Sheet 1 of 2)

Contaminant	Frequent-Use Scenario			Contaminant Total	Occasional-Use Scenario			Contaminant Total
	Pathway				Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
SOIL								
Cesium-137	1E-09	7E-12	2E-06	2E-06	2E-11	1E-13	1E-08	1E-08
Cobalt-60	7E-10	6E-11	8E-06	8E-06	1E-11	1E-12	5E-08	5E-08
Europium-152	3E-10	1E-10	1E-05	1E-05	6E-12	3E-12	6E-08	6E-08
Europium-154	3E-10	1E-10	8E-06	8E-06	6E-12	2E-12	5E-08	5E-08
Uranium[c]	1E-08	2E-07	3E-07	5E-07	2E-10	3E-09	2E-09	5E-09
Total	1E-08	2E-07	3E-05	-	2E-10	3E-09	2E-07	-
High Priority Waste Site Total				3E-05	-			2E-07
SLUDGE								
Cesium-134	3E-07	2E-09	7E-04	7E-04	6E-09	3E-11	4E-06	4E-06
Cesium-137	1E-04	6E-07	>1E-02	>1E-02	2E-06	1E-08	9E-04	9E-04
Cobalt-60	2E-04	2E-05	>1E-02	>1E-02	4E-06	4E-07	>1E-02	>1E-02
Europium-152	7E-05	3E-05	>1E-02	>1E-02	1E-06	6E-07	>1E-02	>1E-02
Europium-154	2E-05	9E-06	>1E-02	>1E-02	4E-07	2E-07	4E-03	4E-03
Europium-155	4E-07	1E-07	9E-04	9E-04	8E-09	3E-09	6E-06	6E-06
Nickel-63	6E-06	4E-07	.b	6E-06	1E-07	7E-09	.b	1E-07
Plutonium-238	3E-06	4E-06	6E-09	7E-06	5E-08	8E-08	4E-11	1E-07
Plutonium-239/240	7E-05	1E-04	1E-07	2E-04	1E-06	2E-06	1E-09	3E-06
Strontium-90	4E-05	6E-07	.b	4E-05	9E-07	1E-08	.b	9E-07

9413274.1313

Table 3-6c. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the Process Effluent Pipeline. (Sheet 2 of 2)

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Uranium[c]	2E-07	3E-06	4E-06	7E-06	3E-09	5E-08	3E-08	8E-08
Total	5E-04	2E-04	>1E-02	-	9E-06	3E-06	>1E-02	-
High Priority Waste Site Total				>1E-02				>1E-02

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Assumed to be uranium-238 (see Chapter 2).
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

WHC-SD-EN-RA-004, Rev. 0

3T-6c-b

Table 3-6d. Summary of the Risk Assessment for Radioactive Contaminants in 2018 at the Process Effluent Pipeline.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
SOIL				
Cesium-137	7E-10	4E-12	9E-07	9E-07
Cobalt-60	2E-11	2E-12	3E-07	3E-07
Europium-152	8E-11	4E-11	3E-06	3E-06
Europium-154	4E-11	2E-11	1E-06	1E-06
Uranium[c]	1E-08	2E-07	3E-07	5E-07
Total	1E-08	2E-07	6E-06	-
High Priority Waste Site Total				6E-06
SLUDGE				
Cesium-134	5E-11	3E-13	1E-07	1E-07
Cesium-137	6E-05	3E-07	>1E-02	>1E-02
Cobalt-60	7E-06	6E-07	>1E-02	>1E-02
Europium-152	2E-05	8E-06	>1E-02	>1E-02
Europium-154	3E-06	1E-06	>1E-02	>1E-02
Europium-155	1E-08	3E-09	2E-05	2E-05
Nickel-63	5E-06	3E-07	_b	5E-06
Plutonium-238	2E-06	3E-06	5E-09	5E-06
Plutonium-239/240	7E-05	1E-04	1E-07	2E-04
Strontium-90	2E-05	3E-07	_b	2E-05
Uranium[c]	2E-07	3E-06	4E-06	7E-06
Total	2E-04	1E-04	>1E-02	-
High Priority Waste Site Total				>1E-02

[a]Lifetime incremental cancer risk.
[b]Not an external exposure hazard.
[c]Assumed to be uranium-238 (see Chapter 2).
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-6e. Estimated Dose for the Great Basin Pocket Mouse at the 100-HR-1 Process Effluent Pipelines (0-6 feet).

Contaminant in soil	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-137	3.40E-02	8.43E-12	1.89E-06	1	1.89E-06
Cobalt-60	3.80E-02	7.60E-12	5.88E-07	1	5.88E-07
Europium-152	1.10E-01	4.40E-14	1.54E-09	1	1.54E-09
Europium-154	7.90E-02	3.16E-14	2.27E-10	1	2.27E-10
Europium-155	3.90E-02	1.56E-11	1.05E-07	1	1.05E-07
Plutonium-238	2.40E-02	6.72E-13	1.07E-07	1	1.07E-01
Plutonium-239/240	1.40E-01	3.92E-12	5.87E-07	1	5.87E-07
Strontium-90	8.80E-02	6.69E-10	7.37E-03	1	7.37E-03
Tritium	1.80E+01	3.47E-08	2.30E-05	1	2.30E-05
Uranium-238	3.00E-01	1.20E-10	2.73E-04	1	2.73E-04
Total Dose			7.67E-03		7.67E-03
Contaminant in sludge	Activity/g Soil (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Cesium-134	5.5	5.50E-10	1.18E-04	1	1.18E-04
Cesium-137	2900	7.19E-07	1.61E-01	1	1.61E-01
Cobalt-60	11,000	2.20E-06	1.70E-01	1	1.70E-01
Europium-152	26,000	1.04E-08	3.65E-04	1	3.65E-04
Europium-154	5700	2.28E-09	1.64E-05	1	1.64E-05
Europium-155	660	2.64E-10	1.78E-06	1	1.78E-06
Nickel-63	18,000	7.20e-07	1.53E-02	1	1.53E-02
Plutonium-238	9.7	2.72E-10	4.33E-05	1	4.33E-05
Plutonium-239/240	230	6.44E-09	9.65E-04	1	9.65E-04
Uranium-238	4.7	1.88E-09	4.28E-03	1	4.28E-03
Tritium	650	3.46E-08	2.30E-05	1	2.30E-05
Strontium-90	950	7.22E-06	7.96E+01	1	7.96E+01
Total Dose			8.00E+01		8.00E+01

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-7a. Historical and LFI Data Summary for the 116-H-7 Sludge Burial Trench.

Parameter	Historical Data[a]				LFI Data		QRA Data		
	Maximum Concentration	1/2 Life (Years)	Maximum Concentration	Depth (ft.)	Maximum Concentration	Depth (ft.)	Concentration Used in QRA		Rationale for Selection
Radionuclides, pCi/g			Decayed to 1992				1992	2018	
Europium-154	0.21	8.8	0.06	15	-	-	0.06	0.0077	maximum concentration detected at or above 15 ft.
Europium-155	0.14	4.96	0.015	15	-	-	0.015	0.00040	maximum concentration detected at or above 15 ft.
Strontium-90	0.38	28.6	0.26	15	-	-	0.26	0.14	maximum concentration detected at or above 15 ft.

- indicates parameter was not analyzed for or not reported.
[a] Dorian and Richards 1976 radiological data (1978).

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-7b. Preliminary Risk-Based Screening for Radioactive Soil Contaminants at the 116-H-7 Sludge Burial Trench.

Parameter	Maximum Soil Concentration in 1992 (pCi/g)	Oral SF[a] (pCi)$^{-1}$	Soil Concentration at Oral ICR = 1E-07 (pCi/g)	Inhalation SF[a] (pCi)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-07 (pCi/g)	External SF[a] (pCi-yr/g)$^{-1}$	Soil Concentration at External ICR = 1E-07 (pCi/g)
Europium-154	0.06	3.0E-12	25	1.4E-10	65	4.1E-06	0.00081
Europium-155	0.015	4.5E-13	170	1.8E-11	510	5.9E-08	0.056
Strontium-90	0.26	3.6E-11	2.1	6.2E-11	150	_b	_b

[a]Health Effects Assessment Summary Tables (HEAST, EPA 1992)
[b]Not an external exposure hazard
ICR = Lifetime incremental cancer risk
SF = Slope factor
Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-7c. Summary of the Risk Assessment for Radioactive Contaminants in 1992 at the 116-H-7 Sludge Burial Trench.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathway			Contaminant Total	Pathway			Contaminant Total
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure		Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]		ICR[a]	ICR[a]	ICR[a]	
Europium-154	2E-10	9E-11	6E-06	6E-06	5E-12	2E-12	4E-08	4E-08
Total	2E-10	9E-11	6E-06	-	5E-12	2E-12	4E-08	-
High Priority Waste Site Total				6E-06				4E-08

[a]Lifetime incremental cancer risk.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-7d. Summary of the Risk Assessment for Radioactive Contaminants in 2018 at the 116-H-7 Sludge Burial Trench.

Contaminant	Frequent-Use Scenario			Contaminant Total
	Pathway			
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	
	ICR[a]	ICR[a]	ICR[a]	
Europium-154	3E-11	1E-11	8E-07	8E-07
Total	3E-11	1E-11	8E-07	-
High Priority Waste Site Total				8E-07

[a]Lifetime incremental cancer risk.
- = Not applicable.

Note: Shaded area indicates screening criterion exceeded.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-7e. Estimated Dose for the Great Basin Pocket Mouse at the 116-H-7
Sludge Burial Trench

Contaminant	Activity/g (pCi/g)	Activity/kg Vegetation (wet) (Ci/kg)	Dose Rate (rad/day)	Fractional Use	Dose Rate (rad/day)
Europium-154	0.06	2.4E-14	1.7E-10	1	1.7E-10
Europium-155	0.015	6.0E-15	4.0E-11	1	4.0E-11
Strontium-90	0.26	2.0E-09	2.1E-02	1	2.0E-02
Total Dose					2.0E-02

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-8a. Risk-Based Concentrations for Radioactive Soil Contaminants at the 116-H-5 Outfall Structure.

Parameters[b]	Frequent-Use Scenario			Occasional-Use Scenario		
	Pathways			Pathways		
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	Soil Ingestion	Fugitive Dust Inhalation	External Exposure
	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)
Americium-241	3.2E+00	2.9E+00	8.5E+00	1.7E+02	1.5E+02	1.3E+03
Cesium-134	1.9E+01	3.3E+03	8.0E-03	9.8E+02	1.7E+05	1.3E+00
Cesium-137	2.7E+01	4.8E+03	2.1E-02	1.4E+03	2.5E+05	3.3E+00
Cobalt-60	5.1E+01	6.1E+02	4.9E-03	2.6E+03	3.2E+04	7.6E-01
Europium-152	3.6E+02	8.3E+02	1.2E-02	1.9E+04	4.3E+04	1.8E+00
Europium-154	2.5E+02	6.5E+02	1.0E-02	1.3E+04	3.4E+04	1.6E+00
Europium-155	1.7E+03	5.1E+03	7.1E-01	8.9E+04	2.6E+05	1.1E+02
Nickel-63	3.2E+03	5.1E+04	_a	1.7E+05	2.6E+06	_a
Plutonium-238	3.5E+00	2.3E+00	1.5E+03	1.8E+02	1.2E+02	2.4E+05
Plutonium-239/240	3.3E+00	2.4E+00	1.5E+03	1.7E+02	1.3E+02	2.4E+05
Potassium-40	6.9E+01	1.2E+04	7.7E-02	3.6E+03	6.3E+05	1.2E+01
Radium-226	6.3E+00	3.0E+01	6.9E-03	3.3E+02	1.6E+03	1.1E+00
Strontium-90	2.1E+01	1.5E+03	_a	1.1E+03	7.7E+04	_a
Thorium-228	1.4E+01	1.2E+00	7.4E-03	7.2E+02	6.1E+01	1.2E+00
Thorium-232	6.3E+01	3.3E+00	1.6E+03	3.3E+03	1.7E+02	2.5E+05
Uranium-238	2.7E+01	1.8E+00	1.2E+00	1.4E+03	9.2E+01	1.8E+02
Zirconium-95	7.7E+02	9.1E+03	1.7E-02	3.9E+04	4.8E+05	2.6E+00

[a] Not an external exposure hazard.
[b] Taken from the 116-H-7 Retention Basin.
- Not applicable.
ICR = Lifetime incremental cancer risk.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 3-8b. Risk-Based Concentrations for Non-Radioactive Soil Contaminants at the 116-H-5 Outfall Structure.

Parameter[f]	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathways				Pathways			
	Soil Ingestion		Fugitive Dust Inhalation		Soil Ingestion		Fugitive Dust Inhalation	
	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)
Arsenic	2.4E+01	3.8E-01[c]	.[a]	1.1E+01[d]	1.3E+03	2.0E+01[c]	.[a]	1.7E+02[d]
Chromium VI	4.0E+02	.[b]	.[a]	4.0E+00	2.1E+04	.[b]	.[a]	2.1E+02
Lead[e]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]

[a] No RfD or SF available to evaluate the pathway.
[b] Not classified as carcinogen or not considered carcinogenic via this exposure route or pathway.
[c] Based on proposed arsenic unit risk of 5E-05 µg/L (IRIS, EPA 1993)
[d] Based on 30% absorption of inhaled arsenic
[e] Regulatory soil cleanup guideline is 500-1000 mg/kg (EPA 1989)
[f] Taken from the 116-H-7 Retention Basin.
- Not applicable.
HQ = Hazard quotient.
ICR = Lifetime incremental cancer risk.

3T-8b

WHC-SD-EN-RA-004, Rev. 0

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-9a. Risk-Based Concentrations for Radioactive Soil Contaminants at the 132-H-3 Pump Station.

Parameters	Frequent-Use Scenario			Occasional-Use Scenario		
	Pathways			Pathways		
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	Soil Ingestion	Fugitive Dust Inhalation	External Exposure
	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)
Americium-241[b]	3.2E+00	2.9E+00	8.5E+00	1.7E+02	1.5E+02	1.3E+03
Carbon-14[c]	8.5E+02	1.4E+07	-[a]	4.4E+04	7.4E+08	-[a]
Cesium-134[b]	1.9E+01	3.3E+03	8.0E-03	9.8E+02	1.7E+05	1.3E+00
Cesium-137[b,c]	2.7E+01	4.8E+03	2.1E-02	1.4E+03	2.5E+05	3.3E+00
Cobalt-60[b,c]	5.1E+01	6.1E+02	4.9E-03	2.6E+03	3.2E+04	7.6E-01
Europium-152[b,c]	3.6E+02	8.3E+02	1.2E-02	1.9E+04	4.3E+04	1.8E+00
Europium-154[b]	2.5E+02	6.5E+02	1.0E-02	1.3E+04	3.4E+04	1.6E+00
Europium-155[b]	1.7E+03	5.1E+03	7.1E-01	8.9E+04	2.6E+05	1.1E+02
Nickel-63[b]	3.2E+03	5.1E+04	-[a]	1.7E+05	2.6E+06	-[a]
Plutonium-238[b]	3.5E+00	2.3E+00	1.5E+03	1.8E+02	1.2E+02	2.4E+05
Plutonium-239/240[b,c]	3.3E+00	2.4E+00	1.5E+03	1.7E+02	1.3E+02	2.4E+05
Radium-226[b]	6.3E+00	3.0E+01	6.9E-03	3.3E+02	1.6E+03	1.1E+00
Strontium-90[b,c]	2.1E+01	1.5E+03	-[a]	1.1E+03	7.7E+04	-[a]
Thorium-228[b]	1.4E+01	1.2E+00	7.4E-03	7.2E+02	6.1E+01	1.2E+00
Thorium-232[b]	6.3E+01	3.3E+00	1.6E+03	3.3E+03	1.7E+02	2.5E+05
Tritium[c]	1.4E+04	1.2E+06	-[a]	7.3E+05	6.1E+07	-[a]
Uranium-238[b]	2.7E+01	1.8E+00	1.2E+00	1.4E+03	9.2E+01	1.8E+02
Zirconium-95[b]	7.7E+02	9.1E+03	1.7E-02	3.9E+04	4.8E+05	2.6E+00

[a] Not an external exposure hazard.
[b] Taken from the 116-H-7 Retention Basin.
[c] Taken from the 132-H-3 surface smear sample, floor and piping, Table A-12.
- Not applicable.
ICR = Lifetime incremental cancer risk.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-9b. Risk-Based Concentrations for Non-Radioactive Soil Contaminants at the 132-H-3 Pump Station.

Parameters[g]	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathways				Pathways			
	Soil Ingestion		Fugitive Dust Inhalation		Soil Ingestion		Fugitive Dust Inhalation	
	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)
Arsenic	2.4E+01	3.8E-01[d]	.a	1.1E+01[e]	1.3E+03	2.0E+01[d]	.a	1.7E+02[e]
Barium	5.6E+03	.b	3.2E+03	.b	2.9E+05	.b	2.4E+05	.b
Cadmium	8.0E+01	.b	.a	2.6E+01	4.2E+03	.b	.a	1.4E+03
Chromium VI	4.0E+02	.b	.a	4.0E+00	2.1E+04	.b	.a	2.1E+02
Cobalt	4.8E+03	.b	.a	.b	2.5E+05	.b	.a	.b
Copper	3.2E+03	.b	.a	.b	1.7E+05	.b	.a	.b
Lead[f]	.a	.a	.a	.a	.a	.a	.a	.a
Manganese	1.1E+04	.b	3.5E+03	.b	5.9E+05	.b	1.8E+05	.b
Mercury	2.4E+01	.b	2.8E+03	.b	1.3E+03	.b	1.5E+05	.b
Molybdenum	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Nickel	1.6E+03	.b	.a	.c	8.3E+04	.b	.a	.c
Selenium	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Silver	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Strontium	4.8E+04	.b	.a	.b	2.5E+06	.b	.a	.b
Vanadium	5.6E+02	.b	.a	.b	2.9E+04	.b	.a	.b
Zinc	2.4E+04	.b	.a	.b	1.3E+06	.b	.a	.b

a No RfD or SF available to evaluate the pathway.
b Not classified as carcinogen or not considered carcinogenic via this exposure route or pathway.
c Nickel is not evaluated because it is not present as carcinogenic refinery dust - see Appendix B.
d Based on proposed arsenic unit risk of 5E-05 µg/L (IRIS, EPA 1993).
e Based on 30% absorption of inhaled arsenic.
f Regulatory soil cleanup guideline is 500-1000 mg/kg (EPA 1989).
g Taken from 132-H-3 sludge sample, Table A-10.
- Not applicable.
HQ = Hazard quotient.
ICR = Lifetime incremental cancer risk.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-10a. Risk-Based Concentrations for Radioactive Soil Contaminants at the 116-H-6 Retention Basin.

Parameters[b]	Frequent-Use Scenario			Occasional-Use Scenario		
	Pathways			Pathways		
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	Soil Ingestion	Fugitive Dust Inhalation	External Exposure
	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation* ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)
Total - Uranium[a]	2.7E+01	1.8E+00	1.2E+00	1.4E+03	9.2E+01	1.8E+02

[a]Uranium-238 is used as a surrogate for total uranium, (see Chapter 2).
[b]From WHC, 1988a.
- Not applicable.
ICR = Lifetime Incremental Cancer Risk

THIS PAGE INTENTIONALLY LEFT BLANK

Table 3-10b. Risk-Based Concentrations for Non-Radioactive Soil Contaminants at the 116-H-6 Retention Basin. (Sheet 1 of 2)

Parameters[g]	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathways				Pathways			
	Soil Ingestion		Fugitive Dust Inhalation		Soil Ingestion		Fugitive Dust Inhalation	
	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)
Ammonia	2.7E+06	.b	9.3E+05	.b	1.4E+08	.b	4.8E+07	.b
Antimony	3.2E+01	.b	.a	.b	1.7E+03	.b	.a	.b
Arsenic	2.4E+01	3.8E-01[e]	.a	1.1E+01[f]	1.3E+03	2.0E+01[e]	.a	1.7E+02[f]
Barium	5.6E+03	.b	3.2E+03	.b	2.9E+05	.b	2.4E+05	.b
Beryllium	4.0E+02	1.5E-01	.a	1.9E+01	2.1E+04	7.8E+00	.a	1.0E+03
Boron	7.2E+03	.b	.a	.b	3.8E+05	.b	.a	.b
Cadmium	8.0E+01	.b	.a	2.6E+01	4.2E+03	.b	.a	1.4E+03
Chloride	.a	.b	.a	.b	.a	.b	.a	.b
Chromium VI	4.0E+02	.b	.a	4.0E+00	2.1E+04	.b	.a	2.1E+02
Cobalt	4.8E+03	.b	.a	.b	2.5E+05	.b	.a	.b
Copper	3.2E+03	.b	.a	.b	1.7E+05	.b	.a	.b
Fluoride	4.8E+03	.b	.a	.b	2.5E+05	.b	.a	.b
Lead[d]	.a	.a	.a	.a	.a	.a	.a	.a
Lithium	.a	.b	.a	.b	.a	.b	.a	.b
Manganese	1.1E+04	.b	3.5E+03	.b	5.9E+05	.b	1.8E+05	.b
Mercury	2.4E+01	.b	2.8E+03	.b	1.3E+03	.b	1.4E+05	.b
Molybdenum	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Nickel	1.6E+03	.b	.a	.c	8.3E+04	.b	.a	.c
Nitrate	1.3E+05	.b	.a	.b	6.7E+06	.b	.a	.b
Nitrite	8.0E+03	.b	.a	.b	4.2E+05	.b	.a	.b
Phosphate	.a	.b	.a	.b	.a	.b	.a	.b
Phosphorus	1.6E+00	.b	.a	.b	8.3E+01	.b	.a	.b

Table 3-10b. Risk-Based Concentrations for Non-Radioactive Soil Contaminants at the 116-H-6 Retention Basin. (Sheet 2 of 2)

Parameters[g]	Frequent-Use Scenario				Occasional-Use Scenario			
	Pathways				Pathways			
	Soil Ingestion		Fugitive Dust Inhalation		Soil Ingestion		Fugitive Dust Inhalation	
	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Soil Concentration at Oral HQ = 1.0 (mg/kg)	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Soil Concentration at Inhalation HQ = 1.0 (mg/kg)	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)
Selenium	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Silicon	.a	.b	.a	.b	.a	.b	.a	.b
Silver	4.0E+02	.b	.a	.b	2.1E+04	.b	.a	.b
Strontium	4.8E+04	.b	.a	.b	2.5E+06	.b	.a	.b
Sulfate	.a	.b	.a .	.b	.a	.b	.a	.b
Thallium Oxide	5.6E+00	.b	.a	.b	2.9E+02	.b	.a	.b
Tin	4.8E+04	.b	.a	.b	2.5E+06	.b	.a	.b
Titanium	.a	.b	.a	.b	.a	.b	.a	.b
Vanadium	5.6E+02	.b	.a	.b	2.9E+04	.b	.a	.b
Zinc	2.4E+04	.b	.a	.b	1.3E+06	.b	.a	.b
Zirconium	.a	.b	.a	.b	.a	.b	.a	.b

[a] No RfD or SF available to evaluate the pathway.
[b] Not classified as carcinogen or not considered carcinogenic via this exposure route or pathway.
[c] Nickel is not evaluated because it is not present as carcinogenic refinery dust - see Appendix B.
[d] Regulatory soil cleanup guideline is 500-1000 mg/kg (EPA 1989).
[e] Based on proposed arsenic unit risk of 5E-05 ug/L (IRIS, EPA 1993).
[f] Based on 30% absorption of inhaled arsenic.
[g] From WHC, 1988a.
- Not applicable.
HQ = Hazard quotient.
ICR = Lifetime incremental cancer risk.

Table 3-11. Risk-Based Concentrations for Radioactive Soil Contaminants at the 132-H-2 Building.

Parameters[b]	Frequent-Use Scenario			Occasional-Use Scenario		
	Pathways			Pathways		
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	Soil Ingestion	Fugitive Dust Inhalation	External Exposure
	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)
Carbon-14	8.5E+02	1.4E+07	_a	4.4E+04	7.4E+08	_a
Cesium-137	2.7E+01	4.8E+03	2.1E-02	1.4E+03	2.5E+05	3.3E+00
Cobalt-60	5.1E+01	6.1E+02	4.9E-03	2.6E+03	3.2E+04	7.6E-01
Europium-152	3.6E+02	8.3E+02	1.2E-02	1.9E+04	4.3E+04	1.8E+00
Europium-154	2.5E+02	6.5E+02	1.0E-02	1.3E+04	3.4E+04	1.6E+00
Plutonium-239	3.3E+00	2.4E+00	2.5E+03	1.7E+02	1.3E+02	3.8E+05
Strontium-90	2.1E+01	1.5E+03	_a	1.1E+03	7.7E+04	_a
Tritium	1.4E+04	1.2E+06	_a	7.3E+05	6.1E+07	_a

aNot an external exposure hazard.
bFrom surface smear, paint and concrete samples, Powers 1986.
- Not applicable.
ICR = Lifetime incremental cancer risk.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 3-12. Risk-Based Concentrations for Radioactive Soil Contaminants at the 132-H-1 Stack.

Parameters[b]	Frequent-Use Scenario			Occasional-Use Scenario		
	Pathways			Pathways		
	Soil Ingestion	Fugitive Dust Inhalation	External Exposure	Soil Ingestion	Fugitive Dust Inhalation	External Exposure
	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)	Soil Concentration at Oral ICR = 1E-06 (pCi/g)	Soil Concentration at Inhalation ICR = 1E-06 (pCi/g)	Soil Concentration at External ICR = 1E-06 (pCi/g)
Carbon-14	8.5E+02	1.4E+07	-[a]	4.4E+04	7.4E+08	-[a]
Cesium-137	2.7E+01	4.8E+03	2.1E-02	1.4E+03	2.5E+05	3.3E+00
Cobalt-60	5.1E+01	6.1E+02	4.9E-03	2.6E+03	3.2E+04	7.6E-01
Europium-152	3.6E+02	8.3E+02	1.2E-02	1.9E+04	4.3E+04	1.8E+00
Strontium-90	2.1E+01	1.5E+03	-[a]	1.1E+03	7.7E+04	-[a]
Tritium	1.4E+04	1.2E+06	-[a]	7.3E+05	6.1E+07	-[a]

[a] Not an external exposure hazard.
[b] From stack core samples, Beckstrom 1987.
- Not applicable.
ICR = Lifetime incremental cancer risk.

THIS PAGE INTENTIONALLY
LEFT BLANK

4.0 SUMMARY AND CONCLUSIONS

This chapter provides a summary of the methods and results of the qualitative risk assessment (QRA) that was performed for the high-priority waste sites in the 100-HR-1 operable unit.

4.1 QUALITATIVE RISK ASSESSMENT PROCESS

The QRA is an evaluation of risk for a predefined set of human and ecological exposure scenarios. The QRA is not intended to replace or be a substitute for a baseline risk assessment. Consequently, the QRA is streamlined to consider only two human health scenarios (frequent and occasional use) with four exposure pathways (soil ingestion, fugitive dust inhalation, inhalation of volatile organics, and external radiation exposure) and a limited ecological evaluation. The use of these scenarios and pathways was agreed to by the 100 Area Tri-Party Unit Managers (December 21, 1992, and February 8, 1993). Future waste site risk estimates considering the decay of radionuclides to the year 2018 and the effect on external radiation exposure by shielding provided by current soil and gravel covers is also presented.

4.1.1 Approach

The QRA is conducted using the HSBRAM (DOE-RL 1993a) as guidance and consists of:

- An evaluation of the data sources and/or process information.

- Identification of maximum constituent concentrations, where data is available.

- A human health risk evaluation.

- An ecological risk evaluation.

- An analysis of potential impacts to groundwater.

Key factors that contribute to uncertainty throughout the risk assessment process are also identified.

4.1.2 Guidelines Used in the Qualitative Risk Assessment

The following guidelines were agreed to by the Tri-Party Unit Managers prior to performing the QRA:

- Site-wide soil background concentration data are used to screen inorganic constituents.

- Historical radionuclide concentrations are decayed to 1992.

- The maximum contaminant concentration within the upper 4.6m (15 ft) of soil, either from historical or LFI data, are used to estimate risk in the QRA.

- Two scenarios, frequent use and occasional use, are evaluated in the human health section of the QRA.

- For the human health exposure assessment, the pathways evaluated in the QRA are: soil ingestion, fugitive dust inhalation, inhalation of volatile organics, and external radiation exposure.

- Ecological scenarios are evaluated using the Great Basin pocket mouse because it is a key component of the Hanford area food chain and a biological endpoint with a range similar in size to the dimensions of most individual waste sites.

Several other guidelines are used in the QRA. The data collection during the LFI for the operable unit followed a known process and therefore the data are considered to be of high quality. Historical data (e.g., Dorian and Richards 1978) are considered to be of medium quality because the data were not validated and documentation was less rigorous. Where historical data do not specify uranium isotopes, uranium-238 is evaluated because it represents >99% of natural uranium. Chromium is assumed to be present as chromium (VI) because it provides the most conservative evaluation and chromium was not speciated during analysis. Nickel in the soil environment is not considered carcinogenic because the pyrolytic activity which generates the carcinogenic form of nickel was not present in the operable unit. If toxicity factors are not available for a constituent, surrogate factors are generally not used, unless specifically noted.

For the QRAs, the following terminology is used to provide relative risk classifications for sites where human health risks are calculated; high (ICR > 1E-02), medium (ICR 1E-02 to 1E-04), low (ICR 1E-04 to 1E-06), and very low (ICR < 1E-06). These classifications are used to categorize the waste sites in a single operable unit based upon their potential risk to human health, in accordance with the objective of the QRA to provide information for the prioritization of waste sites for cleanup activities. A frequent-use scenario is evaluated in 2018 to ascertain potential future risks associated with each waste site after additional radionuclide decay. For the current occasional use scenario, the effect of radiation shielding by the upper 2 m (6 ft) of soil on the external exposure risk at each waste site is evaluated.

For the ecological risk assessment, metals are assumed to be bioavailable for uptake by vegetation. The identified concentrations are assumed to be uniformly distributed over the site, biologically active, and available for transport. Hazard quotients for ecological exposure to radionuclides are based on an exposure limit of 1 rad/day (NCRP 1991) for radionuclides and a NOEL for non-radionuclides.

4.2 HUMAN HEALTH QUALITATIVE RISK ASSESSMENT

The QRA provides estimates of risk that might occur under frequent-use or occasional-use scenarios based on the best available knowledge of current contaminant conditions, but does not represent actual risks since neither frequent-use nor occasional-use of high priority sites currently occurs.

4.2.1 Overview of the Human Health Risk Evaluation Process

The frequent-use and occasional-use scenarios are evaluated using residential and recreational exposure parameters from HSBRAM (DOE-RL 1992a), respectively. Frequent-use is addressed for current (1992) and future (2018) contaminant concentrations. Air inhalation of volatile organics is eliminated from this analysis because volatile organics are not present above preliminary risk-based screening levels in the soil at any waste site. Therefore, inhalation of volatile organics is not a likely exposure pathway for this operable unit. For the soil ingestion and external exposure pathways, maximum sample concentrations from the upper 4.6 m (15 ft) of soil are used. For the fugitive dust inhalation pathway, maximum contaminant concentrations in the upper 4.6 m (15 ft) of soil are used in conjunction with a particulate emission factor. This factor relates contaminant concentrations in the soil to concentrations of respirable particles in the air due to fugitive dust emissions. Quantification of exposures is conducted using Section 2.3 of HSBRAM (DOE-RL 1993a).

The external exposure pathway is also evaluated for the current occasional-use scenario while considering the effect of shielding by existing soil cover. In this evaluation, only radionuclides detected in the upper 2 m (6 ft) of soil are considered as contributors to external radiation exposure. These external exposure risks are considered to be more representative of current site conditions where activities in a contaminated zone are controlled.

Section 2.3 of HSBRAM (DOE-RL 1993a) contains the general procedures followed in the QRA for toxicity assessment. The toxicity assessment in the QRA involves the selection of slope factors and reference doses for contaminants of potential concern and includes sufficient toxicity information on contaminants of potential concern to assist project managers in reaching decisions on IRMs.

Risk characterization for the individual waste sites differs depending on the type and amount of data available for the specific waste site. Risk characterization is conducted in accordance with Section 2.4 of HSBRAM (DOE-RL 1993a). The risk characterization for each site is performed by calculating contaminant-specific ICRs and HQs and then summing contaminant-specific risks to obtain a risk estimate for the waste site.

For sites where sampling data are not available to calculate ICRs and HQs, the risk characterization consists of a qualitative discussion of the site, the potential threat posed by the site, and the confidence in the information available to assess the threat. Risk estimates from analogous sites are used, where appropriate, to qualitatively determine possible contaminants and potential risk levels. The basic intake equations presented in Appendix C are modified to identify soil contaminant concentrations associated with an ICR of 1E-06 or an HQ of 1, using HSBRAM (DOE-RL 1993a) exposure parameters.

4.2.2 Results of the Human Health QRA

An overview of the human health QRA, and associated uncertainties, for the 100-HR-1 QRA are summarized in the following sections.

Information summarized in Tables 4-1, 4-2 and 4-3 for the human health QRA includes:

- · Data availability and confidence in data

- The qualitative risk estimation

- The risk driving contaminants for the frequent-use and occasional-use scenarios

- The risk driving pathways for the frequent-use and occasional-use scenarios

The risk-driving contaminants for both the frequent-use and occasional-use scenarios are generally radionuclides and the primary risk-driving pathway is usually the external exposure pathway.

The high-priority waste sites listed in Table 4-2 of the 100-HR-1 work plan (DOE-RL 1992b) are evaluated in the QRA. Where LFI data were not collected, historical data were used in the risk assessment. Where sampling data were not available, risk estimates from analogous waste sites (if any) were considered in evaluating the potential risk from the waste site.

Based on the QRA, the high-priority waste sites within the 100-HR-1 operable unit are grouped into high, medium, low, and very low risk categories as shown in Table 4-3. The results of the frequent-use scenario are summarized as follows:

- The waste site(s) considered high risk for the frequent-use scenario are the 116-H-1 trench (1992, 2018), 116-H-3 french drain (1992), 116-H-7 retention basin (1992, 2018), and process effluent pipelines (sludge) (1992, 2018).

- The waste site(s) considered medium risk for the frequent-use scenario are the 116-H-2 trench (1992, 2018), 116-H-3 french drain (2018), and 116-H-9 crib (1992, 2018).

- The waste site(s) considered low risk for the frequent-use scenario are the process effluent pipelines (soil) (1992, 2018) and 116-H-7 sludge burial trench (1992).

- The waste site(s) considered very low risk for the frequent-use scenario is the 116-H-7 sludge burial trench (2018).

The results of the occasional-use scenario are summarized as follows:

- The waste site(s) considered high risk for the occasional-use scenario are the 116-H-7 retention basin and process effluent pipelines (sludge). The risk-driving radionuclides at the process effluent pipelines (sludge) waste site are not present in the upper 2 m (6 ft) of soil.

- The waste site(s) considered medium risk for the occasional-use scenario is the 116-H-1 trench.

- The waste site(s) considered low risk for the occasional-use scenario are the 116-H-2 trench, 116-H-3 french drain, and 116-H-9 crib.

- The waste site(s) considered very low risk for the occasional-use scenario are the process effluent pipelines (soil) and 116-H-7 sludge burial trench.

Other results of the QRA as presented in Tables 4-2 and 4-3 are:

- Radionuclides are identified as the primary contributors to the overall risks via the external exposure pathway. The specific radionuclides identified as key contributors are cesium-137, cobalt-60, europium-152, and europium-154.

- For the frequent-use scenario, pathways in addition to external exposure to radionuclides which present estimated risks greater than ICR = 1E-04 and/or HI = 1 include soil ingestion (116-H-1, 116-H-7, 116-H-9, process effluent pipelines-sludge) and fugitive dust inhalation (116-H-7, 116-H-9). No pathways other than external exposure to radionuclides have estimated risks greater than ICR = 1E-04 and/or HI = 1 for the occasional-use scenario.

- There are several sites where potential contaminants are identified only on the basis of historical information and no contaminant concentrations are known. These sites include the 116-H-5 outfall structure, 132-H-2 pump station, 116-H-6 retention basin, 132-H-2 building, 132-H-1 stack, and 116-H-4 crib. Concentrations at which an ICR of 1E-06 or HQ of 1.0 would exist are calculated for the potential contaminants. Estimated risks are considered qualitative estimates and are based on suspected risk-driving contaminants, disposal information, and the size of the waste site.

The risks, both carcinogenic and non-carcinogenic, presented in this QRA are deterministic estimates given multiple assumptions about exposure, toxicity, and variables. Consequently, uncertainty exists for the evaluation of the contaminants, the exposures, the toxicities, and the risk characterization for the QRA. This uncertainty is discussed more extensively in the following sections.

4.2.3 Summary of Key Uncertainties in the Human Health Risk Assessment

In general, the QRA is based on a limited data set. Uncertainties are associated with both the contaminants identified for each waste site and the concentrations of the contaminants. Collected samples may not be representative of conditions throughout the waste site and historical data may not accurately represent current conditions. Because the samples may not be completely representative of the site, risks may be underestimated or overestimated.

Uncertainty exists with respect to the identification of specific contaminants. Where the isotope of uranium is not specified uranium is evaluated as uranium-238. The slope factors for the various uranium isotopes differ slightly from one another, resulting in slightly different risks if each is evaluated separately. The valence state of chromium identified in the QRA samples was not known. For the risk estimate, the most toxic form was assumed (Cr VI). However, risks are overestimated if chromium exists as the less toxic form (Cr III).

External exposure slope factors are appropriate for a uniform contaminant distribution, infinite in depth and areal extent (i.e., an infinite slab source), with no clean soil cover. For high-energy gamma emitters (e.g., cobalt-60 and cesium-137), the assumption of an infinite slab source can only be satisfied if these radionuclides extend to nearly 2 m (6 ft) below ground surface, and over a distance of a few hundred meters or more. If the site being evaluated is smaller than this, or if the site has a clean soil cover, then use of external exposure slope factors is likely to provide risk estimates that are unrealistic. The fact that the external exposure pathway is the risk-driver at many waste sites is not surprising and in some cases may be indicative of the conservatism built into the evaluation of this pathway rather than the actual associated risk.

There is uncertainty associated with the toxicity information available to assess potential adverse effects. The interpretation of the toxicity data and the actual toxicity values used for the QRA are both sources of uncertainty. These uncertainties contribute to the uncertainty in the risk assessment.

When there is a high degree of uncertainty associated with the information used to determine toxicity, there is less confidence in the assessment of the risk associated with exposure. The primary sources of these uncertainties include the following:

- Use of information on dose-response effects from high-dose exposure scenarios to predict effect at low-dose exposure scenarios.

- Use of animal dose-response data to predict effects in humans.

- Use of short-term exposure data to extrapolate to long-term exposure, or vice versa.

- Use of dose-response information from a homogeneous animal or healthy human population to predict the effects that may occur in the general population where there are varying sensitivities to different contaminants.

Uncertainty in the risk characterization also results from summing ICRs and HQs across contaminants and pathways, a process which gives equal weight to toxicity information derived from different sources or species. Exposures to multiple contaminants may result in additive effects or effects that are greater or less than additive.

Historical information and risk estimates form analogous sites may be used to evaluate some of the high-priority waste sites. The selection of analogous sites for the QRA is based on available information at the time the QRA is prepared. As additional information is identified and incorporated into the LFI report for an operable unit, the QRA should be updated to utilize additional pertinent information.

4.3 ECOLOGICAL QUALITATIVE RISK ASSESSMENT

The 100-HR-1 operable unit is a terrestrial waste unit. The approach consistent with the objective of the QRA is to assess the dose to the Great Basin Pocket Mouse. The mouse is used as the indicator receptor because it's home range is comparable to the size of most waste sites and will receive most of it's dose from a waste site.

Ecological Effects. Contaminants found in the soil at waste sites within the 100-HR-1 operable unit include radioactive and nonradioactive elements. For nonradioactive elements, ecological effects were evaluated from uptake from the soil by plants, and by accumulation of these elements through the foodweb. Radioactive elements have ecological effects resulting from their presence in the abiotic environment (external dose), and from ingestion (consumption dose), resulting in a total body burden. Total daily doses to an organism can be estimated as the sum of doses received from all radioactive elements ingested, residing in the body, and available in the organism's environment. Radiological dose calculation methodology as reviewed by Baker and Soldat (1992), were applied in this QRA. The radiological dose an organism receives is usually expressed as rad/day.

Endpoint Selection. The measurement endpoints are the health and mortality of the Great Basin pocket mouse. Risk is evaluated for the pocket mouse based on a two-step accumulation model (soil-to-plant and plant-to-mouse). The dose to the pocket mouse was used to screen the level of risk of an individual waste site.

Risk is evaluated for the Great Basin Pocket Mouse based on a two-step accumulation model. The method of integration is based on averaging waste site constituent concentrations over the operable unit as a fraction of the total operable unit area.

Exposure Analysis. The exposure analysis integrates the spatial and temporal distributions of the ecological components and stressors.

All nonradioactive and radioactive constituents identified as of potential concern in the human health risk assessment (before the risk-based screening) were considered to be of concern in the ecological risk assessment. Because of the lack of site-specific ecologic data, it was assumed the receptor spends some fraction of it's life in the site, obtains all its food from the site when present, and all consumed food is contaminated. However, because there is no source of water within the site, drinking water was not considered a route of exposure.

The major route of all contaminants to plants is assumed to be direct uptake from soil. Ingestion of vegetation is assumed to be a major route of exposure to the mouse, for both nonradiological and radiological constituents. For radionuclides, the exposure pathway considered uptake from contaminated food resulting in internal exposure. For all contaminants, the dose is based on receptor whole-body concentrations. Metals stressors are assumed to be bioavailable for uptake by vegetation.

4.3.1 Results of the Ecological Evaluation

A qualitative ecological risk assessment was completed for the 100-HR-1 operable unit. Sites 116-H-1 Trench, 116-H-2 Trench, 116-H-7 Retention Basin, and the Process Effluent Pipelines (sludge) exceeded the EHQ of 1 rad/day. For sites that exceeded the EHQ, most of the dose is from strontium. The doses to the pocket mouse from radionuclides in the upper soil profile (0-6 ft) were at least as great as that of the total soil profile (0-15 ft). This suggests that the radionuclides (primarily strontium-90) are available within the rooting depth of plants and the burrowing depth of the pocket mice.

For non-radiological constituents, site 116-H-1 Trench exceeded the wildlife NOEL for arsenic; however, the concentration used in the risk characterization is from the total 0-15 ft soil interval. The wildlife NOELs for arsenic, lead, and zinc are exceeded at 116-H-7 Retention Basin (both 0-6 and 0-15 ft scenarios). The 116-H-9 Crib (both 0-6 and 0-15 ft scenarios) exceeded the NOELs for barium, manganese, and vanadium.

4.3.2 Summary of Key Uncertainties in the Ecological Evaluation

The uncertainty in contaminant concentrations for the ecological evaluation is related to the accuracy of the data. For the QRA, uncertainty exists in both contaminants identified and exposure concentrations. As for the human health assessment, the maximum contaminant concentration was used.

The QRA models the potential exposure of wildlife thought present in or near the waste site. The issues of concern with regard to ecological risk assessment (particularly qualitative) are the uncertainties in using an assortment of environmental variables in risk modeling. This begins with the source term. If this number is not realistic, no amount of modeling will overcome this deficiency. For example, in the case of the QRA, the maximum reported waste concentration was used as the source term no matter how deep this concentration.

Generally, site-specific organisms (e.g., pocket mouse), are identified as being associated with a site, but little if any data may exist concerning transfer of contaminants to site-specific organisms. Often, it is necessary to use biological trophic transfer information for related species.

A significant source of uncertainty in the exposure scenario is that the waste site is uniformly contaminated and in the case of the mouse, all foodstuff is assumed to be contaminated. No provision is made for dilution of contaminated foodstuff by non contaminated foodstuff. It was also assumed contaminants were not passed through the gut but completely retained (100% absorption efficiency).

To complete the QRA for the 100-HR-1 operable unit it was necessary to use data from surrogate organisms in place of the pocket mouse since no site data are available for this organism. This contributes to overall QRA uncertainty. In addition, transfer coefficients used to model uptake of contaminants from soil to plants were not Hanford specific, the approach did not consider whether roots of a plant actually grow deep enough to contact a contaminant, and the model did not account for reduced concentrations from plant to seed (it was assumed the seed concentration was the same as the plant). The pocket mouse food consumption rate was generalized and seasonal behavior (hibernation) that would reduce exposure and body burden was not considered.

Uncertainty associated with wildlife toxicity values is significant, particularly for non radiological contaminants. The approach used in the QRA tends to build conservatism into the toxicity value.

5.0 REFERENCES

Argonne, 1992, *RESRAD*, Version 4.3.5, Argonne National Laboratory, Argonne, Illinois.

Baker, D. A., and J. K. Soldat, 1992, *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment*, PNL-8150, Pacific Northwest Laboratory, Richland, Washington.

Bechtold, R.A., 1992, *Data Validation Procedures for Chemical Analyses*, WHC-SD-EN-SPP-002, Westinghouse Hanford Company, Richland, Washington.

Beckstrom, J.F., 1984, *ARCL Calculations for the 117-H Filter Building*, UNI-3001, UNC Nuclear Industries, Richland, Washington.

Beckstrom, F.F., 1987, *ARCL Calculations for Decommissioning the 116-H-Stack*, UNI-3827, UNC Nuclear Industries, Richland, Washington.

Beckstrom, J.F., and R.B. Loveland, 1986, *ARCL Calculations for Decommissioning the 117-D Filter Building*, UNI-3870, UNC Nuclear Industries, Richland, Washington.

Bleyler, R. 1988, *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*, U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.

Childs, H.E. et al., 1966, "Study of Pathological Conditions in Wild Rodents in Radioactive Areas, *American Midland Naturalist*", Vol. 76, pp. 309-324.

Coughtrey, P. J., D. Jackson, C. H. Jones, P. Kane, and M. C. Thorne, 1985, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems*, A. A. Balkema, Rotterdam, Netherlands.

DOE 1990, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5, U.S. Department of Energy, Washington, D.C.

DOE, 1992, *Site-Wide Characterization Report, Fernald Environmental Management Project*, FEMP-SWCR-3, U.S. Department of Energy, Fernald Field Office, Fernald, Ohio.

DOE-RL, 1982, *Site Characterization Report for the Basalt Waste Isolation Project*, DOE/RL 82-3, Rockwell Hanford Operations, Richland, Washington.

DOE-RL, 1991, *Groundwater Model Development Plan in Support of Risk Assessment*, DOE/RL-91-62 Decisional Draft, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992a, *Hanford Site Past-Practice Strategy*, DOE/RL-91-40, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1992b, *Remedial Investigation/Feasibility Study Work Plan for the 100-HR-1 Operable Unit, Hanford Site, Richland Washington*, DOE/RL 88-35, Revision 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993a, *Hanford Site Baseline Risk Assessment Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1993b, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, DOE/RL-92-24, Revision 1, Draft, U.S. Department of Energy, Richland, Washington.

Dorian, J.J., and V.R. Richards, 1978, *Radiological Characterization of the Retired 100 Areas*, UNI-946, United Nuclear Industries, Richland, Washington.

Ecology, EPA and DOE-RL, 1990, *Hanford Federal Facility Agreement and Consent Order*, First amendment, Two volumes, 89-10 Rev. 1, Washington Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Eisler, R., 1985, "Cadmium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review", *Contaminant Hazard Review*, Report No. 2, U.S. Fish and Wildlife Service, Patuxent, M.D.

Eisenbud, M., 1987, *Environmental Radioactivity*, Academic Press, Inc., San Diego, California.

EPA 1988a, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*, EPA/540/G-89/004, OSWER 9355.3-01, U.S. Environmental Protection Agency, Washington D.C.

EPA 1988b, *Superfund Exposure Assessment Manual*, EPA/540/1-88, 001, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA 1989a, *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part A; Interim Final*, EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1989b, *Interim Guidance on Establishing Soil Lead Cleanup levels at Superfund Sites*, OSWER 9355.4-02, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1989c, *Risk Assessment Methodology: Environmental Impact Statement for NESHAPS Radionuclides. Volume I: Background Information Document*, EPA/520/1-89/005, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

EPA, 1991a, *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part B: Development of Risk-Based Remediation Goals; Review Draft*, OSWER 9285.7-01B, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1991b, *Interim Oral RfD for Copper (Tacoma, WA)*, Superfund Health Technology Support Center, U.S. Environmental Protection Agency, Region IV, Cincinnati, Ohio.

EPA, 1992, *Health Effects Assessment Summary Tables: Annual FY-1992*, OHEA/ECAO-CIN-821, March 1992, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1993, *Integrated Risk Information System (IRIS)*, data file, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesday, Maryland.

ERDA, 1975, *Waste Management Operations: Hanford Reservations, Richland, Washington, Final Environmental Statement*, ERDA/1538, Energy Research and Development Administration, Richland, Washington.

French, N. R. et al., 1967, "Life Spans in the Mojave Desert", *Journal of Mammalogy*, Vol. 48, pp. 537-548.

French, N. R., B.G. Maza, H.O. Hill, A.P. Aschwanden, and H.W. Kaaz, 1974, "Population Study of Irradiated Desert Rodents", *Ecological Monographs*, Vol. 44, pp. 45-72.

Gee, G.W., M.J. Fayer, M.L. Rockhold, and M.D. Campell, 1992, "Variations in Recharge at the Hanford Site", *Northwest Science*, Vol. 66, p. 237-250.

HFSUWG, 1992, "Future for Hanford: Uses and Clean-up", Richland, Washington.

Hedlund, J. D., and W. H. Rickard, 1981, "Wildfire and the Short-term Response of Small Mammals Inhabiting a Sagebrush-bunchgrass Community", *The Murrelet*, Vol. 62, pp. 10-14.

IAEA, 1992, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*, Technical Reports Series No. 332, International Atomic Energy Agency, Vienna, Austria.

Kearney, A.T., 1992, *Data Validation Procedures for the 100-HR-1 Operable Unit Vadose Borehole*, WHC-SD-EN-TI-082, Westinghouse Hanford Company, Richland, Washington.

Landeen, D.S., M.R. Sackschewsky, and S.G. Weiss, 1993, *100 Areas CERCLA Ecological Investigations*, WHC-EP-0620, Westinghouse Hanford Company, Richland, Washington.

Miller, M.L., et al., 1977, *Radiochemical Analyses of Soil and Vegetation Samples Taken from the Hanford Environs.*, 1971-1976, BNWL-2249, Pacific Northwest Laboratory, Richland, Washington.

Newell, et al., 1987, *Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife*, Technical Report 87-3, New York State Department of Environmental Conservation.

O'Farrell, T.P., 1975, "Small Mammals, Their Parasites and Pathological Lesions on the Arid Lands Ecology Reserve, Benton County, Washington", *American Midland Naturalist*, Vol. 93, pp. 377-387.,

Powers, E.W., 1986, *117-H Filter Building Decommissioning Individual Facility Report*, UNI-2752, UNC Nuclear Industries, Richland, Washington.

Roberts, J.W., 1991, *Description of Work for the 100-HR-1 Source Operable Unit*, WHC-SD-EN-AP-066, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rose, K. S. B., 1992, "Lower Limits of Radiosensitivity in Organisms, Excluding Man", *Journal of Environmental Radioactivity*, Vol. 15, pp. 113-133.

Routson, R. C., and D. A. Cataldo, 1978, "A Growth Chamber Study of the Effect of Soil Concentration and Plant Age on the Uptake of Sr and Cs by Tumbleweed", *Communications in Soil Science and Plant Analysis*, Vol. 9, pp. 215-230.

Sackschewsky, M. R., and D. S. Landeen, 1992, *Fiscal Year 1991 100 Areas CERCLA Ecological Investigations*, WHC-EP-0448, Westinghouse Hanford Company, Richland, Washington.

Sackschewsky, M. R., D. S. Landeen, G. I. Baird, W. H. Rickard, and J. L. Downs, 1992, *Vascular Plants of the Hanford Site*, WHC-EP-0554, Westinghouse Hanford Company, Richland, Washington.

Schmidt, et al., 1992, *Westinghouse Hanford Company Environmental Surveillance Annual Report Calendar Year 1991*, WHC-EP=0573, Richland, Washington.

Schmidt, J.W., A.R. Johnson, S.M. McKinney and C.J. Perkins, 1993, *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, CY 1992*, WHC-P-0573-1, Westinghouse Hanford Company, Richland, Washington.

Schuler, C. A., W. H. Rickard, and G. A. Sargeant, 1988, *Bird Associations with Shrubsteppe Plant Communities at the Proposed Reference Repository Location in Southeastern Washington*, PNL-6493, Pacific Northwest Laboratory, Richland, Washington.

Semagin, V. N., 1975, "Influence of Prolonged Low Dose Irradiation on Brain of Rat Embryos", *Radiobiologya*, Vol. 15, pp. 583-588.

Serne, R.J., and M.I. Wood, 1990, *Hanford Waste-Form Release and Sediment Interaction: A Status Report with Rationale and Recommendations for Additional Studies*, PNL-7297, Pacific Northwest Laboratory, Richland, Washington.

Stenner, et al., 1988, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford*, PNL-6456, Pacific Northwest Laboratory, Richland, Washington.

Weiss, S.G. and R.M. Mitchell, 1992, *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site*, WHC-EP-0601, Westinghouse Hanford Company, Richland, Washington.

WHC, 1988a, *Interim Status Closure/Post Closure Plan: 183-H Solar Evaporation Basins*, DOE/RL 88-04, Westinghouse Hanford Company for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

WHC, 1988b, *Final Status Post-Closure Permit Application: 183-H Solar Evaporation Basins*, DOE/RL 88-09, Westinghouse Hanford Company for U.S. Department of Energy, Richland, Washington.

Whicker, F.W., and V. Schultz, 1982, *Radioecology: Nuclear Energy and the Environment*, Vol. II, CRC Press, Inc., Boca Raton, Florida.

Wintczak, T.M., 1993, Letter to R.D. Freeberg, DOE, *Validated Data for the 100 Aggregate Area Biota Sampling,* Correspondence No. 9352382D, March 24, 1993, Westinghouse Hanford Company, Richland, Washington. (Approximately 1000 pages)

Woodruff, R.K., and R.W. Hanf, 1992, *Hanford Site Environmental Report for Calendar Year 1991,* PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 4-1. Summary of Data Availability and Data Confidence (for sites where data are available).

Waste Site	Summary of Data Availability and Data Confidence				
	Historical Data[a]	LFI Data[a]	Data from the same Medium[b]	Confidence in Contaminant Identification	Confidence in Contaminant Concentrations
Sites with LFI data and historical data					
116-H-1 trench	R	R,I,O	Yes	high	medium
116-H-2 trench	R	R,I,O	Yes	medium	medium
116-H-3 french drain	R	R,I,O	Yes	high to med.	medium
116-H-7 retention basin	R	R,I,O	No	high	low
116-H-9 crib	-	R,I,O	-	high	high
Sites with historical data only					
Process Effluent Pipelines	R	-	-	medium	low
116-H-7 sludge burial trench	R	-	-	med. to low	low
- = Not applicable [a] R = radionuclide, I = inorganic, O = organic contaminant [b] LFI and Historical Data are from the same medium (e.g., both from soil) or from different media (e.g., soil and sludge)					

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Table 4-2. Human Health Data and Risk Assessment Summary (for sites where only process knowledge is available).

Site	Disposal Information	Suspected Risk-Driving Contaminants	Description and Notes	Qualitative Risk Rating[a]	Rationale for Rating
116-H-5 outfall structure	Unknown volume of treated process effluent from the 116-H-7 retention basin between 1949 and 1965.	Co-60, Eu-152, Eu-154, As	Compartmented concrete box measuring 378 x 27 x 14 ft.	medium	116-D-5 outfall structure in the 100-DR-1 operable unit has a high risk estimate.
132-H-3 pump station	Pumped water from H reactor drains from 1949 to 1965. Sump water and sludge removed in 1987.	Co-60, Cs-134, Ra-226, Th-228, As, Hg	Demolished and buried in-situ in 1987. Backfilled with a minimum of 15 ft of clean fill.	low	Building rubble buried under 15 ft of fill.
116-H-6 retention basin	Received fuel fabrication wastes from the N reactor, treated wastes by solar evaporation. Received wastes through 1985.	uranium, P, thallium oxide, As, Hg, Sb, Be	Four concrete basins measuring 45 x 33 x 10 ft. Decommissioned in 1991.	medium	Possible effluent leakage; high volume of liquid waste received.
132-H-2 building	Filtered reactor exhaust air prior to emission using HEPA and halogen filters.	Co-60, Sr-90, Cs-137, Eu-152, Eu-154	59 x 39 x 35 ft. concrete building, 90% below ground. Demolished and buried in-situ in 1983 and covered with 3 ft of soil.	low	Building rubble buried under 3 ft. of fill; filters removed.
132-H-1 stack	Emitted filtered air from the 132-H-2 building. Documented radionuclide release in 1955.	Co-60, Sr-90, Cs-137, Eu-152	200 x 16 ft concrete stack, demolished in 1983 and covered with 3 ft of soil.	low	Building rubble buried under 3 ft of soil.
116-H-4 crib	Received low volumes of cooling water during periods of fuel element failure; discharged waste from fuel element failure.	(See 132-H-2 building evaluation)	4 x 4 x 2 ft crib used from 1950 to 1952. Excavated in 1960 to a depth of 30 ft for construction of 132-H-2 building on same site.	low (See 132-H-2 building evaluation)	Crib was in service only two years, has been excavated to a 30 ft depth.

[a] Rating is qualitative based on process information, analogous site information, and site-specific information such as size, potential contaminants, and location of contaminations as indicated under rationale column.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 4-3. Human Health Risk Assessment Summary (for sites where data are available).

Waste Site	Human Health Risk Assessment Summary				
	Frequent-Use Scenario			Occasional-Use Scenario	
	Qualitative Risk Estimation		Risk Driving Contaminant[a] (and pathway[b])	Qualitative Risk Estimation (1992)	Risk Driving Contaminant[a] (and pathway[b])
	1992	2018			
Sites with LFI and historical data					
116-H-1 trench	high	high	R(E) I(O)	medium	R(E)
116-H-2 trench	medium	medium	R(E)	low	-
116-H-3 french drain	high	medium	R(E)	low	-
116-H-7 retention basin	high	high	R(O,I,E)[c] I(O)	high	R(E)
116-H-9 crib	medium	medium	R(E) I(O,I)	low	R(E)
Sites with historical data only					
process effluent pipelines (soil)	low	low	-	very low	-
process effluent pipelines (sludge)	high	high	R(O,I,E)	high	R(E)
116-H-7 sludge burial trench	low	very low	-	very low	-

- = None present.
[a] R = radionuclide, I = inorganic, O = organic contaminant (at ICR = 1E-04, HI = 1).
[b] O = oral, I = inhalation, E = external exposure pathways.
[c] Only the external exposure pathway has the risk-driving contaminants for 2018.

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 4-4. Environmental Hazard Quotients Summary for Radionuclides by Waste Site.

Waste Site	Soil Depth (feet)	Dose Rate Exceeds EHQ of 1 rad/day
116-H-1 Trench	0-6	yes
116-H-1 Trench	0-15	yes
116-H-2 Trench	0-6	yes
116-H-2 Trench	0-15	yes
116-H-3 Drain	0-6	no
116-H-3 Drain	0-15	no
116-H-7 Retention Basin	0-6	yes
116-H-7 Retention Basin	0-15	yes
116-H-9 Crib	0-6	no
116-H-9 Crib	0-15	no
Process Effluent Pipelines (Soil)	0-6	no
Process Effluent Pipelines (Sludge)	0-6	yes
116-H-7 Sludge Burial Trench	0-15	no

THIS PAGE INTENTIONALLY
LEFT BLANK

Table 4-5. Environmental Hazard Quotient Summary for Non-radiological
Contaminants by Waste Site.

Contaminant	Soil Depth (feet)	Dose Rate Exceeds Wildlife NOEL
116-H-1 Trench	0-15	yes-arsenic
116-H-7 Retention Basin	0-6	yes-arsenic, lead, zinc
116-H-7 Retention Basin	0-15	yes-arsenic, lead, zinc
116-H-9 Crib	0-6	yes-barium, manganese, vanadium
116-H-9 Crib	0-15	yes-barium, manganese, vanadium

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX A

HISTORICAL DATA

This historical data presented in this appendix are referenced in Chapter 3.0 in the Qualitative Risk Assessment.

References:

DOE-Rl, 1992b, *Remedial Investigation/Feasibility Study Work Plan for the 100-HR-1 Operable Unit, Hanford Site, Richland, Washington,* DOE/RL 88-35, Revision 0. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Dorian, J.J., and V.R. Richards, 1978, *Radiological Characterization of the Retired 100 Areas,* UNI-946, United Nuclear Industries, Richland, Washington.

WHC, 1988a, *Interim Status Closure/Post-Closure Plan: 183-H Solar Evaporation Basins,* DOE-Rl 88-04, Westinghouse Hanford Company for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

TABLES:

THIS PAGE INTENTIONALLY
LEFT BLANK

Table A-1a. 116-H-7 Retention Basin Sample Holes. (Sheet 1 of 2)

107-H RETENTION BASIN

SAMPLE HOLES DRILLED OUTSIDE OF BASIN

Concentration (pCi/g)

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	C-14
A 20	*	2.3×10^{-1}	9.8×10^{-1}		<200	1.6×10^{-1}	*	*	*	*	*		
B 15					<200	8.6×10^{0}	7.1×10^{0}	3.2×10^{0}	1.4×10^{-1}	2.2×10^{0}	1.3×10^{0}		
16	3.0×10^{-1}	3.2×10^{0}	9.5×10^{0}		1000	2.3×10^{2}	1.9×10^{2}	6.8×10^{1}	*	8.2×10^{1}	1.3×10^{1}	4.0×10^{-1}	*
20	*	1.2×10^{0}	4.7×10^{0}		600	1.6×10^{2}	1.2×10^{2}	4.7×10^{1}	*	1.8×10^{1}	7.3×10^{0}		
25	*	*	6.8×10^{-1}		<200	1.6×10^{0}	9.0×10^{-1}	3.4×10^{-1}	*	3.8×10^{0}	1.8×10^{0}		
C 15	*	*	3.8×10^{-1}		<200	*	*	2.1×10^{-1}	*	*	1.4×10^{-1}		*
D 10					<200	3.8×10^{-1}	7.2×10^{-2}	*	8.0×10^{-2}	1.2×10^{0}	2.2×10^{-1}		
20	*	*	1.4×10^{0}		<200	3.6×10^{-1}	3.8×10^{-2}	*	*	3.1×10^{-2}	3.7×10^{-2}	2.8×10^{-1}	*
H 5					<200	*	*	*	*	*	1.5×10^{-1}		
15	*	*	2.0×10^{-1}		<200	1.6×10^{-1}	*	*	*	3.4×10^{-2}	1.9×10^{-1}		*
19-1/2	*	1.5×10^{0}	1.0×10^{0}		1000	4.7×10^{2}	2.4×10^{2}	1.3×10^{2}	*	1.5×10^{1}	2.4×10^{1}		*
25	*	*	5.9×10^{-1}		200	3.5×10^{1}	2.6×10^{1}	1.1×10^{1}	*	7.5×10^{0}	2.3×10^{0}	5.1×10^{-1}	*
30	*	*	5.0×10^{-1}		<200	3.5×10^{0}	2.3×10^{0}	1.2×10^{0}	*	2.7×10^{0}	5.9×10^{-1}		
I 10					<200	*	*	*	*	*	2.5×10^{-1}		
20	*	*	5.1×10^{-1}		<200	1.2×10^{0}	8.7×10^{0}	5.8×10^{-1}	*	2.9×10^{0}	2.1×10^{-1}		
25	*	5.0×10^{-1}	8.7×10^{-1}		1000	3.2×10^{2}	3.0×10^{2}	1.1×10^{2}	*	1.4×10^{1}	1.9×10^{1}	4.1×10^{-1}	*
30	*	*	4.9×10^{-1}		<200	*	1.5×10^{-1}	*	*	5.2×10^{0}	1.6×10^{-1}		
J 15					<200	*	*	*	*	*	1.8×10^{-1}		
25	*	*	6.3×10^{-1}		<200	4.7×10^{-1}	3.0×10^{0}	3.2×10^{-1}	*	1.8×10^{0}	1.2×10^{-1}		
35	*	*	1.1×10^{0}		<200	1.6×10^{-1}	*	*	*	5.1×10^{-1}	*		
K 10	*	1.9×10^{-1}	3.3×10^{-1}		<200	7.1×10^{-1}	5.3×10^{-1}	*	*	*	1.0×10^{-1}		
15	*	1.6×10^{-1}	4.1×10^{0}		500	4.2×10^{1}	1.0×10^{2}	1.6×10^{1}	*	4.1×10^{1}	3.5×10^{0}	4.1×10^{-1}	*
20	*	*	2.5×10^{0}		300	4.9×10^{1}	3.1×10^{1}	1.4×10^{1}	*	1.2×10^{1}	2.7×10^{0}		
30	*	*	2.0×10^{0}		<200	1.6×10^{1}	2.3×10^{1}	4.4×10^{0}	*	2.6×10^{1}	1.2×10^{0}		
L 5	*	*	5.8×10^{-2}		<200	2.9×10^{-1}	8.9×10^{-2}	*	*	6.8×10^{-2}	8.3×10^{-2}		
10	*	1.2×10^{0}	6.9×10^{-1}		600	1.6×10^{2}	1.3×10^{2}	5.3×10^{1}	*	6.7×10^{0}	7.6×10^{0}		
15	*	1.9×10^{0}	1.8×10^{1}		400	9.8×10^{1}	7.2×10^{1}	3.3×10^{1}	*	6.2×10^{1}	5.4×10^{0}	3.5×10^{-1}	*
20	*	*	8.9×10^{-1}		<200	1.0×10^{0}	3.8×10^{-1}	3.0×10^{-1}	*	3.1×10^{1}	2.3×10^{-1}		
25	*	*	1.2×10^{0}		<200	1.7×10^{0}	9.2×10^{-1}	8.8×10^{-1}	*	2.2×10^{1}	5.6×10^{-2}		
M 10					<200	2.0×10^{-1}	*	*	*	*	2.4×10^{-1}		
15	*	*	8.7×10^{-2}	4.4×10^{-1}	<200	1.0×10^{-1}	1.5×10^{-1}	*	*	9.9×10^{-2}	6.7×10^{-2}	2.0×10^{-1}	*

Location C was drilled into the sludge burial trench east of the 116-H-7 retention basin.

Source: Dorian and Richards 1978.

Table A-1a. 116-H-7 Retention Basin Sample Holes. (Sheet 2 of 2)

107-H RETENTION BASIN

SAMPLE HOLES DRILLED OUTSIDE OF BASIN

Concentration (pCi/g)

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	C-14
N 10	*	*	6.0×10^{-1}		<200	*	*	*	*	*	9.5×10^{-2}		
18	*	*	1.1×10^{-1}		<200	*	6.0×10^{-2}	*	*	4.5×10^{-2}	1.1×10^{-1}	1.9×10^{-1}	*
O 5	*	*	2.0×10^{-1}		<200	1.9×10^{-1}	7.2×10^{-2}	*	*	3.4×10^{-2}	3.0×10^{-1}		
10	*	5.2×10^{-1}	1.0×10^{0}		500	1.1×10^{2}	6.0×10^{1}	4.1×10^{1}	*	3.3×10^{1}	7.4×10^{0}		
15	7.9×10^{-2}	5.9×10^{-1}	3.1×10^{0}		450	1.8×10^{2}	8.0×10^{2}	5.7×10^{1}	*	3.9×10^{1}	1.1×10^{1}		
P 10	*	*	*		<200	*	*	*	*	*	*		
20	*	*	3.3×10^{0}	5.3×10^{-1}	<200	1.9×10^{-1}	2.7×10^{-1}	*	*	*	5.1×10^{-2}	3.8×10^{-1}	*
30	*	*	3.1×10^{-2}		<200	*	6.1×10^{-2}	*	*	4.2×10^{-2}	1.0×10^{-1}		
Q 10	2.7×10^{-2}	1.4×10^{-1}	1.3×10^{-1}		<200	*	*	2.8×10^{-1}	*	3.0×10^{-2}	6.0×10^{-2}		
20	*	1.3×10^{-2}	2.6×10^{-2}	7.4×10^{-1}	<200	*	*	*	*	*	8.6×10^{-1}	2.9×10^{-1}	
25	*				<200	*	*	*	*	*	2.4×10^{-1}		
30	*	*	3.4×10^{-2}		<200	1.9×10^{-1}	*	*	*	*	8.8×10^{-2}		
W 10	*	*			<200	*	*	*	*	4.9×10^{-2}	3.6×10^{-1}		
15	*	*	2.3×10^{-2}		<200	*	*	*	*	3.6×10^{-2}	*		
20	*	*	1.7×10^{0}	4.3×10^{1}	<200	2.5×10^{-1}	3.1×10^{-1}	*	*	4.7×10^{-2}	*	3.0×10^{-1}	
30	*	*	*		<200	*	5.0×10^{-2}	*	*	*	1.0×10^{-1}		
River Beach Sample	*	1.3×10^{-1}	8.7×10^{-1}	1.4×10^{0}	<200	*	1.0×10^{-1}	3.6×10^{-1}	*	2.5×10^{-1}	8.5×10^{-2}	4.5×10^{-1}	

Source: Dorian and Richards 1978

Table A-1b. 116-H-7 Retention Basin Sample Holes.

107-H RETENTION BASIN

SAMPLE HOLES DRILLED INSIDE OF BASIN

Concentration (pCi/g)

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	Ni-63	C-14
X 1	*	*	1.3×10^{0}		<200	1.6×10^{-1}	*	*	*	4.7×10^{-2}	*			
2	*	*	9.8×10^{-1}		<200	3.8×10^{-1}	*	*	*	5.2×10^{-2}	7.8×10^{-2}			
2-1/2	*	4.7×10^{-1}	3.0×10^{2}		200	7.8×10^{1}	1.9×10^{1}	2.6×10^{1}	*	2.0×10^{0}	2.3×10^{0}			
3	5.1×10^{-1}	1.4×10^{1}	1.4×10^{1}	1.9×10^{1}	10,000	8.1×10^{1}	2.1×10^{2}	2.7×10^{2}	1.2×10^{3}	3.0×10^{1}	1.3×10^{1}	8.3×10^{-1}	1.2×10^{3}	*
3C	1.5×10^{-1}	3.9×10^{1}	4.4×10^{1}		3,000	3.6×10^{1}	9.1×10^{1}	1.4×10^{2}	5.2×10^{2}	6.2×10^{1}	8.3×10^{1}		5.2×10^{2}	
5-1/2	*	*	1.8×10^{-1}	3.7×10^{0}	200	8.7×10^{1}	8.5×10^{1}	2.9×10^{1}	*	1.5×10^{2}	1.6×10^{0}	4.4×10^{-1}		*
7-1/2	*	*	8.9×10^{-1}		<200	5.0×10^{-1}	3.2×10^{-1}	*	*	1.4×10^{0}	9.7×10^{-2}			
12-1/2	*	*	6.7×10^{0}		<200/20	2.2×10^{-1}	7.1×10^{-2}	*	*	3.6×10^{0}	1.1×10^{-1}			
Y 1	*	*	2.5×10^{-2}		<200	1.7×10^{-1}	*	*	*	8.6×10^{-2}	1.3×10^{-1}			
2	*	8.0×10^{-1}	1.1×10^{0}		<200	*	5.5×10^{-2}	*	*	3.1×10^{-2}	*			
3	*	5.5×10^{-1}	4.7×10^{0}		<200	7.5×10^{1}	2.5×10^{1}	2.4×10^{1}	*	3.6×10^{0}	3.7×10^{0}			
4	*	*	5.6×10^{-1}		<200	3.1×10^{1}	1.6×10^{1}	*	*	1.1×10^{-1}	1.7×10^{-1}			
4-1/2	1.0×10^{0}	2.2×10^{1}	2.5×10^{0}		3,000	3.8×10^{3}	1.3×10^{3}	1.7×10^{3}	*	2.9×10^{2}	6.6×10^{1}			
5	1.4×10^{0}	3.2×10^{1}	2.4×10^{1}	5.5×10^{1}	40,000	3.9×10^{4}	1.8×10^{4}	2.0×10^{4}	8.9×10^{1}	2.9×10^{3}	9.9×10^{2}	4.7×10^{0}	2.0×10^{4}	*
5-1/2	*	9.8×10^{0}	3.7×10^{1}		3,000	1.0×10^{3}	4.8×10^{2}	4.8×10^{2}	*	2.2×10^{2}	4.9×10^{1}			
7-1/2	*	*	2.8×10^{0}	1.7×10^{1}	200	5.5×10^{-1}	5.8×10^{-1}	8.3×10^{-1}	*	2.1×10^{1}	2.5×10^{-1}	1.6×10^{-1}		*
10	*	1.8×10^{-1}	1.5×10^{0}		<200/30	7.4×10^{0}	8.5×10^{0}	2.5×10^{0}	*	1.7×10^{1}	*			
12	*	1.8×10^{-1}	6.6×10^{-1}		<200/30	5.0×10^{0}	1.3×10^{1}	1.8×10^{0}	*	8.7×10^{0}	1.1×10^{-1}			

Source: Dorian and Richards 1978

Table A-2. 116-H-7 Rentention Basin Fill.

107-H RETENTION BASIN FILL

BASIN SLUDGE

Ave. Depth = 2"   Mass = 1.9 x 10⁹g

Concentrations (pCi/g)

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	Ni-63	C-14
AS 4	*	4.4×10^0	2.6×10^1	3.0×10^0	5.6×10^2	2.8×10^2	2.2×10^2	*	2.9×10^1	7.6×10^0	4.0×10^{-1}		
DS 4-1/2	1.7×10^0	5.6×10^1	8.2×10^1	4.1×10^0	1.4×10^4	2.8×10^3	3.9×10^3	1.8×10^1	5.2×10^2	2.9×10^2	9.2×10^{-1}		
AN 4-1/2	*	9.0×10^{-1}	1.4×10^1	3.9×10^0	9.2×10^1	8.4×10^1	4.8×10^1	*	1.8×10^2	1.2×10^1	2.2×10^{-1}		
BN 4	1.5×10^0	3.9×10^1	7.4×10^1	3.7×10^2	7.3×10^3	3.1×10^3	2.5×10^3	2.9×10^1	1.9×10^2	6.2×10^3	5.2×10^{-1}		
CN 4	7.7×10^0	2.0×10^2	3.5×10^2	2.2×10^2	2.0×10^4	5.0×10^3	6.5×10^3	2.9×10^1	1.2×10^3	1.7×10^2	3.4×10^0	4.7×10^3	
DN 4	4.0×10^0	1.1×10^2	1.2×10^2	2.4×10^2	1.2×10^4	3.1×10^3	3.7×10^3	*	5.7×10^2	1.7×10^2	1.2×10^0		
X 3	5.1×10^{-1}	1.4×10^1	1.4×10^2	1.9×10^1	8.1×10^2	2.1×10^2	2.7×10^2	1.2×10^3	3.0×10^1	*	8.3×10^{-1}	1.2×10^3	*
Y 5	1.4×10^0	3.2×10^1	2.4×10^1	5.5×10^1	3.9×10^4	1.8×10^4	2.0×10^4	8.9×10^1	2.9×10^3	9.9×10^2	4.7×10^0	2.0×10^4	*
Ave. pCi/g	2.1	5.7×10^1	1.0×10^2	1.3×10^2	1.2×10^4	4.1×10^3	4.6×10^3	5.4×10^1	7.0×10^2	1.1×10^3	1.5	8.6×10^3	0.0
Curies	4.0×10^{-3}	1.1×10^{-1}	1.9×10^{-1}	2.5×10^{-1}	23	7.8	8.7	1.0×10^{-1}	1.3	2.1	2.9×10^{-3}	16	0.0

Total Curies In Sludge = 60

A-4

WHC-SD-EN-RA-004, Rev. 0

Source: Dorian and Richards 1978

Table A-3. 116-H-7 Basin Effluent Pipe and Inlet Distribution Box.

Sample No.	Description					Concentration (pCi/g)							
		^{238}Pu	$^{239/240}$Pu	^{90}Sr	^{3}H	^{152}Eu	^{60}Co	^{154}Eu	^{134}Cs	^{137}Cs	^{155}Eu	U	^{63}Ni
Z-1	Loose scale from a piece of vent pipe lying on the distribution chamber floor.	4.3×10^{0}	1.1×10^{2}	5.4×10^{1}		2.1×10^{4}	8.2×10^{4}	8.4×10^{3}	*	9.7×10^{2}	5.5×10^{2}		
Z-2	Sludge along distribution chamber floor.	1.1×10^{1}	2.3×10^{2}	1.4×10^{3}	1.6×10^{3}	5.9×10^{4}	9.3×10^{4}	1.1×10^{4}	1.9×10^{1}	4.2×10^{3}	6.9×10^{2}	3.3×10^{0}	
Z-3	Scale from inside inlet effluent line to distribution chamber.	1.0×10^{0}	1.4×10^{1}	2.1×10^{1}	1.3×10^{2}	2.8×10^{3}	2.3×10^{2}	9.7×10^{2}	2.4×10^{0}	2.1×10^{1}	4.2×10^{1}	1.3×10^{0}	1.4×10^{2}
Z-4	Cement chips from wall surrounding inlet effluent line to distribution chamber.	*	5.4×10^{0}	2.0×10^{1}		3.8×10^{3}	4.2×10^{2}	1.2×10^{3}	1.9×10^{0}	8.0×10^{1}	2.4×10^{2}		
Z-5	Pieces of charred wood lying at west end of distribution chamber.	*	4.9×10^{0}	3.5×10^{1}	3.5×10^{1}	1.1×10^{3}	1.1×10^{3}	3.4×10^{2}	*	1.5×10^{2}	4.6×10^{1}		

*Less than analytical detection limit.
Note: Blanks indicate data was not reported by the original authors.
Source: Dorian and Richards 1978.

A-5

WHC-SD-EN-RA-004, Rev. 0

Table A-4. Soil Column Along Effluent Lines to the 116-H-7 Retention Basin.

SOIL COLUMN

ALONG EFFLUENT LINES TO 107-H BASIN

<u>Description</u> - Location is between two expansion boxes in the effluent lines running to the 107-H basins, approximately 200' from southwest corner of basins.

Radionuclide	Ave. pCi/g	Max. pCi/g
Pu-238	*	*
Pu-239/240	*	*
Sr-90	1.3×10^{-2}	2.3×10^{-2}
H-3	4.3×10^{1}	4.3×10^{1}
Eu-152	6.3×10^{-2}	2.5×10^{-1}
Co-60	9.0×10^{-2}	3.1×10^{-1}
Eu-154	*	*
Cs-134	*	*
Cs-137	3.3×10^{-2}	4.9×10^{-2}
Eu-155	1.2×10^{-1}	3.6×10^{-1}
U	3.0×10^{-1}	3.0×10^{-1}

Source: Dorian and Richards 1978

Table A-5. Soil Column Along Effluent Lines from 116-H-7 Retention Basin to Outfall Structure.

SOIL COLUMN

ALONG EFFLUENT LINES FROM 107-H BASIN TO OUTFALL STRUCTURE

Radionuclide	Ave. pCi/g	Max. pCi/g
Pu-238	9.0×10^{-3}	2.7×10^{-2}
Pu-239/240	5.1×10^{-2}	1.4×10^{-1}
Sr-90	6.3×10^{-2}	1.3×10^{-1}
H-3	7.4×10^{-1}	7.4×10^{-1}
Eu-152	4.8×10^{-2}	1.9×10^{-1}
Co-60	*	*
Eu-154	7.0×10^{-2}	2.8×10^{-1}
Cs-134	*	*
Cs-137	7.5×10^{-3}	3.0×10^{-2}
Eu-155	1.2×10^{-1}	2.4×10^{-1}
U	2.9×10^{-1}	2.9×10^{-1}
C-14	*	*

Source: Dorian and Richards 1978

Table A-6. 116-H-1 Trench.

116-H-1

107-H LIQUID WASTE DISPOSAL TRENCH

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Concentration (pCi/g) Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	C-14
E 15	*	*	1.4×10^{-1}		<200	*	*	*	*	*	*		*
F 2	3.2×10^{-1}	6.6×10^{0}	5.2×10^{1}		3000	1.2×10^{3}	2.8×10^{2}	3.1×10^{2}	*	5.8×10^{2}	4.2×10^{1}		*
G 15	*	*	5.5×10^{-2}		<200	5.5×10^{-1}	*	2.9×10^{-1}	*	*	3.0×10^{-1}		
G 20	*	*			<200	*	*	*	*	4.6×10^{-2}	1.0×10^{-1}		*
R 5					<200	2.9×10^{0}	6.8×10^{-1}	5.0×10^{-1}	3.8×10^{-2}	1.3×10^{0}	4.7×10^{-1}		*
R 15	*	*	4.8×10^{-1}	9.7×10^{-1}	<200	5.1×10^{0}	1.0×10^{0}	1.7×10^{0}		2.8×10^{0}	6.7×10^{-1}		*
R 18	3.5×10^{-1}	1.3×10^{-1}	8.2×10^{1}		3000	1.8×10^{3}	4.4×10^{2}	5.9×10^{2}		5.2×10^{2}	9.3×10^{1}	3.1×10^{-1}	*
R 20	*	*	3.6×10^{0}		<200	5.4×10^{1}	1.4×10^{1}	1.4×10^{1}		6.5×10^{1}	1.8×10^{0}		
R 25	*	*	1.3×10^{1}		<200	3.1×10^{0}	3.7×10^{-1}	3.2×10^{-1}		9.5×10^{-1}	4.2×10^{-2}		
S 15	*	*	5.4×10^{-1}		<200	3.7×10^{0}	9.8×10^{-1}	1.2×10^{0}		1.9×10^{0}	3.8×10^{-1}		
S 18	*	2.4×10^{-1}	1.9×10^{0}		200	5.3×10^{1}	1.2×10^{1}	1.2×10^{1}		2.7×10^{1}	1.4×10^{0}		
S 23	*	1.8×10^{0}	1.6×10^{1}		600	2.5×10^{2}	6.1×10^{1}	6.5×10^{1}		5.6×10^{1}	8.0×10^{0}		
S 25	*	*	2.6×10^{0}		<200	1.5×10^{0}	5.5×10^{-2}	6.2×10^{-1}	4.0×10^{-2}	7.5×10^{-2}	1.0×10^{-1}		
T 10					<200	4.0×10^{-1}	*	*	*	1.6×10^{-1}	2.2×10^{-1}		
T 20	*	*	2.4×10^{0}	6.3×10^{-1}	<200	4.3×10^{0}	4.2×10^{-1}	6.8×10^{-1}	*	3.6×10^{0}	3.3×10^{-1}		
T 25					<200	4.4×10^{0}	5.3×10^{-1}	1.0×10^{0}	*	4.1×10^{0}	3.0×10^{-1}	1.6×10^{-1}	*
U 10					<200	4.6×10^{0}	8.4×10^{-1}	9.9×10^{-1}	*	1.8×10^{0}	*		
U 15	*	2.0×10^{1}	1.8×10^{0}		<200	6.3×10^{0}	1.2×10^{0}	1.1×10^{0}	*	2.2×10^{0}	3.3×10^{-1}		
U 17-1/2	3.1×10^{-1}	1.1×10^{1}	8.2×10^{1}		2000	2.1×10^{3}	1.8×10^{2}	2.5×10^{3}	*	4.0×10^{2}	3.0×10^{1}		
U 20	*	2.4×10^{-1}	1.7×10^{0}		200	3.3×10^{1}	4.6×10^{1}	8.4×10^{0}	*	1.2×10^{2}	1.8×10^{0}	3.0×10^{-1}	
U 25	*	*	1.3×10^{0}		<200	1.1×10^{0}	1.5×10^{-1}	4.8×10^{-1}	*	3.6×10^{-1}	*		
V 10					<200	4.1×10^{0}	7.9×10^{0}	1.7×10^{0}	*	3.2×10^{1}	1.5×10^{-1}		
V 15					<200	1.2×10^{0}	*	2.0×10^{-1}	3.4×10^{-2}	5.3×10^{-1}	3.4×10^{-1}		
V 20	*	*	2.5×10^{0}		<200	9.1×10^{-1}	7.2×10^{-2}	2.8×10^{-1}	*	1.0×10^{-1}	*		

Source: Dorian and Richards 1978

Table A-7. 116-H-2 Trench and 116-H-3 French Drain Soil Concentrations.

116-H MISC. CRIBS & TRENCHES

Concentration (pCi/g)

Sample No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U
116-H-2 160B-H TRENCH												
A 1	*	1.3×10^{-1}	7.3×10^{1}	1.9×10^{0}	400	2.7×10^{1}	6.4×10^{0}	6.2×10^{0}	8.2×10^{-2}	2.8×10^{-1}	2.5×10^{0}	4.5×10^{-1}
5	*	*	3.3×10^{1}	6.8×10^{0}	<200/100	3.8×10^{-1}	2.6×10^{-1}	2.2×10^{-1}	3.3×10^{-2}	1.4×10^{0}	3.5×10^{-1}	2.0×10^{-1}
10			1.9×10^{-1}		<200/20	*	*	*	*	*	*	
B 2-1/2	*	*	5.4×10^{1}	1.1×10^{0}	<200/100	4.3×10^{-1}	2.7×10^{-1}	*	*	1.4×10^{1}	5.6×10^{-1}	1.5×10^{-1}
5	*	*	1.2×10^{-1}		<200/10	*	*			3.5×10^{-2}	*	
C 5	*	*	5.0×10^{1}	1.1×10^{1}	<200/150	2.6×10^{0}	3.6×10^{0}	1.0×10^{0}	*	7.7×10^{1}	9.5×10^{-1}	1.7×10^{-1}
10			1.0×10^{0}		<200/20	*	4.1×10^{-2}	*		1.1×10^{0}	5.4×10^{-2}	
D 10	*	*	1.3×10^{1}	4.5×10^{1}	<200/80	7.0×10^{-1}	6.6×10^{-1}	*	*	1.4×10^{1}	2.1×10^{-1}	1.8×10^{-1}
E 15	*	*	1.1×10^{-1}		<200/35	*	*	*	3.1×10^{-2}	1.1×10^{-1}	7.0×10^{-2}	
F 10	*	*	1.8×10^{-1}		<200/40	*	*	1.3×10^{-1}	*	6.5×10^{-2}	8.3×10^{-2}	
116-H-3 105-H DUMMY DECONTAMINATION DRAIN												
A 15	*	2.7×10^{-1}	5.6×10^{-1}	4.4×10^{0}	<200/60	2.0×10^{0}	1.6×10^{0}	1.1×10^{0}	*	1.1×10^{2}	2.2×10^{0}	
C 4						7.2×10^{1}	3.0×10^{1}	1.7×10^{1}	*	5.7×10^{1}	9.0×10^{-1}	
D 4						2.4×10^{1}	1.1×10^{2}	8.0×10^{0}	*	2.1×10^{2}	4.0×10^{-1}	

A-1 -- Surface sample from south end of trench.

Samples C-4 & D-4 were some preliminary characterization samples taken in 1961. The results were decay corrected to 12/30/75.
C-4 & D-4 were taken 4 feet and 2-1/2 feet away, respectively, from the trench drain.

Source: Dorian and Richards 1978

A-9

WHC-SD-EN-RA-004, Rev. 0

Table A-8 Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 1 of 8)

Basin No. 1 (Inner[a]) Sludge

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	2,100	1,800 - 2,400
Sb		
As		
Ba	nd	
Be		
B	nd	
Cd		
Ca	800	700 - 1,000
Cl		
Cr	900	700 - 1,000
Co		
Cu	119,000	100,000 - 112,000*
F		
Fe	1,700	1,300 - 1,900
Pb		
Li	nd	
Mg	nd	
Mn	1,200	1,000 - 1,400
Hg		
Mo		
Ni	100	<100 - 200
NO_3	80,000	60,000 - 100,000
NO_2		
PO_4		
P	1,100	900 - 1,300
K		
Se		
Si	8,100	7,200 - 9,300
Ag		
Na	200,000	180,000 - 240,000
Sr		
SO_4	200,000	180,000 - 240,000
Tl		
Sn		
Ti	100	70 - 200
TOC		
U	420	390 - 530
V		
H_2O	220,000	190,000 - 250,000
Zn	300	300 - 400
Zr	30,000	20,000 - 40,000

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 2 of 8)

Basin No. 1 (Outer[b]) Sludge

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	4,600	1,300 - 7,900
Sb		
As		
Ba	75	100 - 50
Be		
B	100	100 - 100
Cd		
Ca	1,800	500 - 3,100
Cl		
Cr	450	400 - 500
Co		
Cu	58,500	54,000 - 63,000
F	69,000	67,000 - 71,000
Fe	2,200	1,000 - 3,400
Pb		
Li	80	100 - 60
Mg	725	<500 - 1,200
Mn	750	700 - 800
Hg		
Mo		
Ni	300	<400 - 400
NO$_3$	15,000	14,000 - 16,000
NO$_2$		
PO$_4$		
P		
K		
Se		
Si	17,000	6,000 - 28,000
Ag		
Na	217,000	205,000 - 229,000
Sr		
SO$_4$	341,000	327,000 - 355,000
Tl		
Sn		
Ti	225	<100 - 400
TOC		
U	119	83 - 155
V		
H$_2$O	229,500	228,000 - 231,000
Zn	300	300 - 300
Zr	17,000	16,000 - 18,000

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 3 of 8)

Basin No. 2 Liquid

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	36	30 - 44
Sb	nd	<5
As	nd	<7
Ba		
Be		
B	63	<30 - 97
Cd	nd	<0.06
Ca	9	<5 - 13
Cl	290	260 - 320
Cr	20	16 - 23
Co	1	<0.4 - 1
Cu	410	120 - 940
F	1,500	1,400 - 1,600
Fe	7	3 - 1,400
Pb	nd	<5
Li	nd	<300
Mg	nd	<5
Mn	7	<4 - 13
Hg		
Mo	1	<1 - <2
Ni	9	8 - 10
NO_3	380,000	310,000 - 430,000
NO_2	890	790 - 1,020
PO_4	nd	<300
P		
K	720	670 - 820
Se	nd	<10
Si	2	1 - 3
Ag		
Na	140,000	120,000 - 160,000
Sr	1	<0.5 - 1
SO_4	8,000	7,800 - 8,300
Tl	nd	<10
Sn	15	10 - 25
Ti		
TOC		
U		
V	nd	<2
H_2O	570,000	570,000 - 580,000
Zn	3	1 - 5
Zr	780	320 - 1,500

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 4 of 8)

Basin No. 2 Sludge

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	1,950	540 - 4,470
Sb		
As		
Ba		
Be	6	4 - 8
B		
Cd	334	158 - 634
Ca		
Cl		
Cr	450	292 - 727
Co		
Cu		<3 - <9
F	130,000	99,000 - 154,000
Fe	11,000	5,700 - 18,100
Pb	1,066	641 - 1,559
Li		
Mg		
Mn		
Hg		
Mo	1	<0.4 - 3
Ni		
NO$_3$		
NO$_2$	135,000	82,000 - 175,000
PO$_4$		
P		
K		
Se		
Si		
Ag	24,000	6,000 - 93,000
Na	218	119 - >308
Sr	97,000	42,000 - 159,000
SO$_4$		
Tl	38,000	6,500 - 152,000
Sn		
Ti		
TOC		
U	1,905	237 - 3,828
V	1,250	28 - 2,500
H$_2$O	2	<1.3 - 3
Zn	527,000	457,000 - 577,000
Zr	32,000	28,000 - 35,000

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 5 of 8)

Basin No. 3 Crystalline Material

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	810	780 - 880
Sb	nd	<30
As		
Ba	8	<10 - 3
Be	1	<4 - 1
B	2,700	2,200 - 3,000
Cd	nd	<3
Ca	83	48 - 140
Cl	50	<10 - 180
Cr	21	7 - 40
Co	<3	<3 - <3
Cu	9,900	4,200 - 18,000
F	36,000	29,000 - 49,000
Fe	97	48 - 180
Pb	<30	<30 - <30
Li	nd	<2,000
Mg	29	<20 - 37
Mn	66	31 - 140
Hg		
Mo	nd	<8
Ni	11	<10 - 13
NO$_3$	<10,000	<10,000 - <10,000
NO$_2$	nd	<230
PO$_4$	nd	<520
P		
K	<100	<100 - <100
Se		
Si		
Ag	11	<5 - 17
Na	420,000	350,000 - 550,000
Sr	3	<3 - 5
SO$_4$	200,000	160,000 - 260,000
Tl	<50	<50 - <50
Sn	39	<20 - 73
Ti		
TOC		
U	25	8 - 62
V	nd	<10
H$_2$O	11,000	5,500 - 18,000
Zn	33	17 - 52
Zr	6,200	560 - 15,000

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 6 of 8)

Basin No. 3 Sludge

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	8,900	1,100 - 17,000
Sb	nd	<90
As	nd	100
Ba	6	<1.0 - 22
Be	2	<0.5 - 4
B	40	<20 - <60
Cd	6	4 - <9
Ca	290	180 - 650
Cl	310	150 - 410
Cr	390	290 - 530
Co	5	<3 - <9
Cu	112,000	88,000 - 140,000
F	13,000	9,800 - 15,000
Fe	710	540 - 1,000
Pb	<80	<80 - <80
Li	nd	<5,000
Mg	67	nd - 120
Mn	970	800 - 1,100
Hg		
Mo	nd	<20
Ni	130	96 - 180
NO$_3$	260,000	170,000 - 290,000
NO$_2$	660	430 - 790
PO$_4$	nd	<430
P		
K	680	<300 - 1,600
Se	nd	<200
Si		
Ag	190	120 - 290
Na	230,000	200,000 - 300,000
Sr	17	11 - 36
SO$_4$	37,000	19,000 - 53,000
Tl	nd	<200
Sn	480	360 - 750
Ti		
TOC		
U	870	320 - 1,560
V	<30	<30 - <30
H$_2$O	420,000	350,000 - 510,000
Zn	370	280 - 520
Zr	87,000	22,000 - 220,000

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 7 of 8)

Basin No. 4 Crystalline Material

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	440	200 - 610
Sb	nd	<30
As	nd	<40
Ba	2	1 - 3
Be	0.4	<0.09 - 0.6
B	1,400	300 - 2,700
Cd	nd	<3
Ca	61	43 - 100
Cl	110	<20 - 330
Cr	6	3 - 11
Co	3	1 - <6
Cu	2,600	1,700 - 4,500
F	22,000	2,800 - 58,000
Fe	77	42 - 150
Pb	14	<5 - <20
Li	nd	<2,000
Mg	26	nd - 35
Mn	20	nd - 34
Hg		
Mo	nd	<8
Ni	7	<2 - <10
NO$_3$	466,000	71,000 - 710,000
NO$_2$	nd	<230
PO$_4$	nd	<520
P		
K	56	<20 - 130
Se	nd	<60
Si		
Ag	12	nd - 32
Na	380,000	300,000 - 500,000
Sr	2	<3 - 1
SO$_4$	130,000	15,000 - 310,000
Tl	34	<10 - <50
Sn	58	<5 - 150
Ti		
TOC		
U	12	7 - 20
V	nd	<10
H$_2$O	66,000	11,000 - 250,000
Zn	12	7 - 20
Zr	1,300	290 - 3,300

Table A-8. Results of Inorganic Analyses on 116-H-6 Retention
Basin Wastes. (sheet 8 of 8)

Basin No. 4 Sludge

Analyte	Average Concentration (mg/kg)	Concentration Range (mg/kg)
Al	430	390 - 490
Sb	nd	<90
As	nd	100
Ba	24	<1 - 39
Be	0.4	<0.09 - 1.8
B	31	26 - 38
Cd	4	3 - 5
Ca	84	67 - 110
Cl	210	170 - 230
Cr	260	210 - 340
Co	2	nd - 3
Cu	103,000	97,000 - 120,000
F	11,000	9,800 - 12,000
Fe	2,100	1,200 - 3,800
Pb	36	14 - <50
Li	nd	<5,000
Mg	21	15 - 32
Mn	760	680 - 890
Hg		
Mo	nd	<20
Ni	96	81 - 110
NO_3	220,000	200,000 - 240,000
NO_2	390	330 - 460
PO_4	nd	<430
P		
K	330	78 - 430
Se	nd	<200
Si		
Ag	170	140 - 220
Na	240,000	230,000 - 260,000
Sr	4	4 - 5
SO_4	19,000	13,000 - 39,000
Tl	nd	<200
Sn	600	470 - 680
Ti		
TOC		
U	520	144 - 820
V	4	<2 - <10
H_2O	460,000	430,000 - 510,000
Zn	360	310 - 420
Zr	44,000	3,400 - 130,000

Source: WHC 1988a.
Note: nd = not detected, blank = not analyzed
[a]Samples taken away from the basin walls.
[b]Samples taken near the basin walls.
[*]As presented in WHC 1988a.

Table A-9. 132-H-3 Sump Water Analysis.

Parameter	Sample Number 86298	Sample Number 86299	Units
total suspended solids	13.0	<5.00	mg/L
specific conductivity	415	432	µmho/cm
pH	7.62	7.56	std. units
beryllium	<5.00	<5.00	µg/L
osmium	<300	<300	µg/L
strontium	<100	<300	µg/L
zinc	14.0	15.0	µg/L
calcium	55,600	52,600	µg/L
barium	33.0	32.0	µg/L
cadmium	<2.00	<2.00	µg/L
chromium	<10.0	<10.0	µg/L
silver	<10.0	<10.0	µg/L
sodium	22,400	21,000	µg/L
nickel	<10.0	<10.0	µg/L
copper	<10.0	10.0	µg/L
vanadium	<5.00	<5.00	µg/L
antimony	<100	<100	µg/L
aluminum	<150	<150	µg/L
manganese	16.0	15.0	µg/L
potassium	10,500	9,960	µg/L
iron	74.0	124	µg/L
arsenic	<5.00	6.60	µg/L
mercury	<0.100	0.125	µg/L
selenium	<0.500	<5.00	µg/L
magnesium	6,790	6,560	µg/L
lead	6.40	7.20	µg/L
total organic carbon	5,290	5,200	µg/L
nitrate	4,050	4,000	µg/L
sulfate	77,400	68,800	µg/L
fluoride	<500	<500	µg/L
chloride	5,160	5,170	µg/L
phosphate	<1,000	<1,000	µg/L
ammonium	80.0	73.0	µg/L
total dissolved solids	330	243	mg/L
alkalinity	150	151	mg/L

Source: DOE-RL 1992b

Table A-10. 132-H-3 Sludge Leached with Concentrated
Hydrochloric and Nitric Acids.

Parameter	Concentrations (µg/L)	
	Sample No.: 87 - 155	Sample No.: 87 - 156
Al	7,000	3,700
As	37	29
Ba	220	500
Ca	8,400	8,900
Cd	15	18
Co	9.0	9
Cr	580	410
Cu	940	180
Fe	640,000	630,000
Li	10	8
Mg	5,300	5,000
Mn	480	1,090
Mo	25	16
Na	200	300
Ni	80	47
P	1,200	1,900
Pb	900	850
Sr	34	41
Ti	380	260
V	25	19
Zn	1,200	1,300
Ag	<10	<10
Se	<10	<10
Hg	16	27
Source: DOE-RL 1992b		

Table A-11. 132-H-3 Pumping Station Sump Sludge Extraction Procedure Toxicity Analysis.

Parameter	Concentration (mg/L)	
	Sample No.: 87 - 155	Sample No.: 87 - 156
As	<0.08	<0.08
Ba	1.19	0.97
Cd	0.16	0.06
Cr	<0.02	<0.02
Pb	0.56	0.08
Hg	<0.0001	<0.0001
Ag	<0.01	<0.01
Source: DOE-RL 1992b		

Table A-12. 132-H-3 Pump Station 32 Feet Below Grade.

STANDARD SMEARS/100 CM^2

pCi/Sample

LOCATION	Pu-238	Pu-239/240	Sr-90	H-3	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	C-14
1608-11 Pump House											
Floor											
Floor	*	3.8×10^0	3.4×10^1	7.2×10^2	1.4×10^2	1.5×10^2	*	*	1.5×10^2	*	7.2×10^3
Piping	*	9.9×10^{-1}	1.2×10^0		*	1.7×10^1	*	*		*	

Source: Dorian and Richards 1978

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX B

TOXICOLOGICAL INFORMATION

References:

Amdur, M.O., J.D. Doull, and C.D. Klaussen, editors, 1991, *Casarett and Doull's Toxicology: The Basic Science of Poison*, 4th Edition, Pergamon Press, New York, New York.

Clayton, G.D., and F.E. Clayton, editors, 1981, *Patty's Industrial Hygiene and Toxicology*, 3rd edition, John Wiley and Sons, Inc., New York, New York.

DOE-RL, 1993a, *Hanford Site Baseline Risk Assessment Methodology*, DOE-RL 91-45, Rev. 2, U.S. Department of Energy, Richland, Washington.

Eisenbud, M., 1987, *Environmental Radioactivity*, Academic Press, Inc., San Diego, California.

EPA, 1992, *Health Effects Assessment Summary Tables: Annual FY- 1992*, OHEA/ECAO-CIN-821, March 1992, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1993, *Integrated Risk Information System (IRIS)*, data file, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

THIS PAGE INTENTIONALLY
LEFT BLANK

The purpose of Appendix B is to present toxicological information for contaminants of potential concern identified at the 100-HR-1 operable unit. The categories of information include:

- general background information
- exposure route
- acute toxicity
- chronic toxicity
- carcinogenicity
- supporting information

Data sources for the information provided in the appendix include EPA documents and standard reference texts. These sources are:

- EPA Integrated Risk Information System [(IRIS)] (EPA 1993)
- EPA Health Effects Assessments Summary Tables [HEAST] (EPA 1992)
- Toxicological Profiles for Individual Compounds, Agency for Toxic Substances and Disease Registry
- Casarett and Doull's Toxicology, the Basic Science of Poisons (Amdur, et al. 1991)
- Patty's Industrial Hygiene and Toxicology (Clayton and Clayton 1981)

Table B-1a and B-1b summarize the carcinogenic toxicity values (i.e, slope factors) for the radioactive and non-radioactive substances, respectively. Table B-2 summarizes the non-carcinogenic toxicity values (i.e. RfDs) and the corresponding critical effects for all inorganics, organics and ions analyzed qualitatively in Section 3.0. The following toxicological profiles are for those contaminants that failed preliminary risk-based screening and are assessed quantitatively. Additional information for the toxicity values is discussed in HSBRAM (DOE/RL 91-45, 1993a).

TOXICITY PROFILES FOR
RADIOACTIVE CONTAMINANTS OF POTENTIAL CONCERN

All radionuclides are classified by EPA as Group A human carcinogens due to their property of emitting ionizing radiation. For radium, this classification is based on direct human epidemiological evidence. For the remaining radionuclides, this classification is based on the knowledge that these elements are deposited in the body, delivering calculable doses of ionizing radiation to the tissues. Despite differences in radiation type, energy or half-life, the health effects of ionizing radiation are identical, but may occur in different target organs and at different activity levels.

Cancer induction is the only human health effect of concern resulting from exposure to radioactive environmental contamination, since the concentrations of radionuclides associated with significant carcinogenic effects are typically orders of magnitude lower than those associated with systemic toxicity. The cancers produced by radiation cover the full range of carcinomas and sarcomas, many of which have been shown to be induced by radiation.

EPA's Health Assessment Summary Tables (HEAST; EPA 1992) and Eisenbud (1987) are used as the source of radionuclide information including half-lives, lung class, gastro-intestinal (GI) absorption, and slope factors.

AMERICIUM-241

Americium-241 (Z=95) is a product of neutron activation of uranium in fission reactors and nuclear weapons detonations. It is a decay product of plutonium-241, and has a half-life of 432 yr. Americium-241 decays (to radioactive neptunium-237) by alpha emission, making it an important inhalation and ingestion hazard. Americium-241 is classified as lung class W with a GI absorption factor of 0.1%. Upon intake, it deposits mainly in the bone and liver, from which it is removed very slowly.

CESIUM-134

Cesium-134 (Z = 55) is a neutron activation product produced in nuclear reactors. It has a half-life of 2.06 yr, and decays by beta emission to stable barium-134. This decay releases high energy gamma rays, making cesium-134 an important external exposure hazard [external SF = 5.6×10^{-6} (pCi-yr/g)$^{-1}$]. All cesium isotopes are assigned lung class D, and a GI absorption factor of 100%. Cesium is an alkali metal with properties similar to potassium and rubidium. Metabolism of cesium resembles that of potassium such that it is distributed uniformly throughout the body.

CESIUM-137

Cesium-137 (Z = 55) is a fission product, and is a pure beta emitter with a half-life of 30.2 years. Its short lived daughter, barium-137m, is a high-energy, high-intensity gamma emitter, making cesium-137 an important external exposure hazard [external SF = 2.0×10^{-6} (pCi-yr/g)$^{-1}$]. The metabolism of cesium resembles that of potassium, such that isotopes of this element are readily absorbed and distributed throughout the body (GI absorption factor of 100%, lung class D).

COBALT-60

This neutron activation product (Z = 27) decays through beta emission (to stable nickel-60), and emits high energy, high intensity gammas, making this radionuclide a very important external exposure hazard [external SF = 8.6×10^{-6} (pCi-yr/g)$^{-1}$]. Cobalt-60 has a physical half-life of 5.27 yr, lung class Y, and GI absorption of 30%.

EUROPIUM (152, 154, 155)

There are three potentially important isotopes of europium (Z = 63): europium-152 (half-life = 13.6 yr), europium-154 (8.8 yr), and europium-155 (5.0 yr). Europium-152 decays by beta emission to stable gadolinium-152. It emits a multitude of high energy gamma rays, making it an important external exposure hazard [external SF = 3.6×10^{-6} (pCi-yr/g)$^{-1}$]. Europium-154 decays by beta emission to stable gadolinium-154. This isotope is also an important external exposure hazard [external SF = 4.1×10^{-6} (pCi-yr/g)$^{-1}$]. Europium-155 decays by beta emission to stable gadolinium-155, and is not particularly hazardous by any pathway. All europium isotopes are classified as lung class W with a GI absorption factor of 0.1%.

NICKEL-63

Nickel-63 (Z = 28) is a neutron activation product with a half-life of 100 yr. It is a low energy beta emitter, and has no associated photon emissions. Therefore, it is a relatively small ingestion and inhalation hazard, and is not an external exposure hazard. Nickel is assigned a lung class W, and a GI absorption factor of 5%.

PLUTONIUM (238, 239, 240)

Like many transuranic elements, plutonium (Z = 94) exists largely because it is artificially produced in nuclear reactor fuels and nuclear weapons testing. Plutonium isotopes must have existed in nature at one time, but their half-lives are short enough that they disappeared long ago. The plutonium isotopes of concern (atomic mass numbers 238, 239, 240) have half-lives of 88, 2.4×10^4, and 6.6×10^3 yr, respectively. All three isotopes decay by alpha emission, making them important inhalation and ingestion hazards. Plutonium-238 decays to uranium-234, and plutonium-239 decays to uranium-235. Both uranium isotopes are part of long decay chains (see uranium profile below). Plutonium-240 decays to uranium-236, which in turn decays (by alpha emission) to naturally occurring thorium-232. Because plutonium-239 and -240 cannot be distinguished by alpha spectrometry, the two nuclides are usually reported together as plutonium-239/240.

Studies in animals clearly indicate that bone, liver, and lung (by inhalation) cancers are caused by plutonium exposure. However, available (and limited) human epidemiology studies have not yet shown unequivocal association between plutonium exposure and cancer (56FR33050). EPA classification of plutonium as a Group A, human carcinogen is therefore based on analogy with other radionuclides and the fact that plutonium emits ionizing radiation. Plutonium is considered a lung class Y, with a GI absorption of 0.1%. The fraction of plutonium that does enter the blood stream deposits mainly on the bone surface and liver, from which it is removed very slowly.

POTASSIUM-40

Potassium-40 (Z = 19) is a naturally occurring primordial radionuclide. It decays by beta emission (half-life = 1.28×10^9 yr) to stable calcium-40. Because of its relative abundance and its energetic beta emission (1.3 MeV), potassium-40 is easily the predominant radioactive component in normal foods and human tissues. The potassium-40 content of the human body is on the order of 0.1 μCi, providing a whole body dose of about 17 mrem/yr. Potassium is assigned a lung class D, and a GI absorption factor of 100%. Potassium-40 is a relatively small ingestion and inhalation hazard, but is a relatively important external exposure hazard [external SF = 9.6×10^{-7} (pCi-yr/g)$^{-1}$] due to high-energy gamma emission.

RADIUM-226

Radium-226 (Z = 88) is a daughter product of uranium-238. It decays (half-live = 1600 yr) to radon-222, a noble gas. Because it is an alpha-emitter, radium-226 is an important ingestion and inhalation hazard. One of its daughter products (bismuth-214) is a high-energy gamma emitter, making the decay chain an important external hazard as well.

EPA classifies radium-226 as a Group A, human carcinogen based upon clear evidence of carcinogenicity to humans and animals (56FR33050). Most information on human health effects of radium comes from epidemiological studies of two groups: radium-dial painters in the early part of this century who ingested a considerable amount of radium paint, and patients in Europe injected with a short-lived isotope of radium (radium-224) for treatment of spinal arthritis and tuberculosis infection of the bone. Because radium is chemically similar to calcium, it is sequestered in bone. EPA classifies radium as a lung class W, with a GI absorption of 20%. Scientists have long recognized that exposed radium dial painters have elevated rates of two rare types of cancer (bone sarcomas, and carcinomas of head sinuses and mastoids). This conclusion is supported by the excess incidence of bone sarcomas among laboratory animals injected with radium-226. At high levels of exposure to radium, several non-cancer health effects occur: benign bone growths, osteoporosis, severe growth retardation, tooth breakage, kidney disease, liver disease, tissue necrosis, cataracts, anemia, immunological suppression, and death.

STRONTIUM-90

This fission product (Z = 38), along with its daughter, yttrium-90, is only an internal hazard since both radionuclides have negligible gamma emissions. Strontium-90 is a relatively important ingestion hazard (ingestion SF = 3.3×10^{-11} pCi^{-1}). Strontium-90 has a physical half-life of 28.8 years. Yttrium-90 has a short half-life (64 hr) and, therefore, exists in equilibrium with its parent. Being chemically similar to calcium, this element deposits in the bone and is removed very slowly. Bone cancer is the primary health effect of concern from intakes of radioactive isotopes of strontium. Strontium-90 is assigned a lung class D, and a GI absorption factor of 30%.

THORIUM-228

Thorium-228 (Z = 90) is a naturally occurring as well as man-made actinide. It is a relatively short-lived (half-life = 1.9 yr) daughter of the primordial radionuclide, thorium-232. The decay of thorium-228 is followed by seven short-lived daughters before becoming stable lead-208. One of these daughters (thallium-208) is a high-energy, high-intensity gamma

emitter, making the decay chain an important external hazard [external SF = 5.6×10^{-6} (pCi-yr/g)$^{-1}$]. Thorium-228 itself is an alpha emitter and, therefore, an important internal hazard (ingestion SF = 5.5×10^{-11} pCi^{-1}; inhalation SF = 7.8×10^{-8} pCi^{-1}). Following ingestion or inhalation, thorium is largely deposited in the bone, from which it is released very slowly. Thorium is classified as lung class Y, and has a small GI absorption factor (0.02%).

THORIUM-232

Thorium-232 (Z = 90) is a naturally occurring primordial radionuclide. It is the head of the thorium decay chain, members of which ultimately decay to stable lead-208. Thorium-232 accounts for 100% of naturally occurring thorium. This isotope is also produced in fission reactors as a result of neutron activation of uranium fuels. Because it decays by alpha emission (half-life ≈ 1.4×10^{10} yr), thorium-232 is a particularly important inhalation hazard [inhalation SF = 2.8×10^{-8} (pCi)$^{-1}$]. Thorium is assigned a lung class Y, and a GI absorption factor of 0.02%.

URANIUM (233, 234, 235, 238, total)

The uranium (Z = 92) isotopes of concern (atomic mass numbers 233, 234, 235, and 238) are all naturally occurring as well as man-made. Total uranium is largely made up of uranium-234, -235, and -238. Uranium-238 (half-life = 4.5×10^9 yr) is naturally present at 99.27 wt% with respect to the other uranium isotopes. Uranium-238 is the parent of a long decay chain, one daughter of which is uranium-234 (half-life = 2.4×10^5 yr; naturally present at 0.0057 wt%). Uranium-235, naturally present at 0.72 wt%, is often enriched for its use as a fission reactor fuel, and has a half-life of 7.0×10^8 yr. Uranium-233 is not naturally occurring, and is created as the result of neutron activation of thorium-232. Because they are all alpha emitters, these isotopes of uranium are of greatest concern from ingestion and inhalation pathways. In addition, daughters of uranium-238 and uranium-235 are high-energy gamma emitters, and can make the decay chains important external hazards. Following ingestion or inhalation, uranium concentrates in the kidney and bone. Uranium is assigned a lung class Y, and a GI absorption factor of 5%. Natural uranium has a low specific activity (7.1×10^{-7} Ci/g), meaning its emission of ionizing radiation is relatively weak. Therefore, chemical damage to the kidney is likely to be more important than radiation damage. The proposed national primary drinking water standard for uranium (30 pCi/L; 56FR33050) is based on kidney toxicity.

ZIRCONIUM-95

Zirconium-95 (Z = 40) is created as the result of neutron activation of zirconium-94. It decays by beta emission (half-life ≈ 64 d) to radioactive niobium-95, which subsequently decays to stable molybdenum-95. Zirconium-95 is a high energy, high intensity gamma emitter, making it an important external exposure hazard [external SF = 2.5×10^{-6} (pCi-yr/g)$^{-1}$]. However, it is not persistent due to its short half-life; it decays to approximately 1% of its original activity after 1 yr. Zirconium is assigned a lung class W and a GI absorption factor of 0.2%.

TOXICITY PROFILES FOR NON-RADIOACTIVE
CONTAMINANTS OF POTENTIAL CONCERN

ARSENIC

Arsenic is a common element found in the earth's crust usually in the form of arsenic bearing minerals. Arsenic compounds have found use as pesticides, herbicides, wood preservatives, pigments, and medicinal agents. Depending on the chemical species, arsenic can be toxic via all routes of exposure. Long term exposure to arsenic compounds can result in hyperpigmentation, hyperkeratosis (thickening, drying, and cracking of the skin and growth of warts), and skin cancer. Skin cancer has been primarily associated with ingestion of drinking water containing high levels of arsenic. Chronic exposure through inhalation of arsenic compounds can produce weakness, loss of appetite, nausea, occasional vomiting and diarrhea, and lung cancer.

The EPA has set an oral RfD of 3E-04 mg/kg-d for arsenic. The adverse effects of concern are keratosis and hyperpigmentation. Arsenic is a human carcinogen (EPA weight-of-evidence-classification Group A) known to produce lung cancer from inhalation and skin cancer from ingestion of drinking water. The inhalation slope factor (SF) listed in IRIS is $5.0E+01$ $(mg/kg-d)^{-1}$, based on air monitoring and some biomonitoring exposure assessments in large populations of smelter workers.

BARIUM

Barium is a silvery-white metal that occurs in nature in many different forms. It is found naturally in drinking water and food. Barium and barium compounds are commonly used in various industries and in human health care. For example, barium carbonate, barium chloride and barium hydroxide are used to make ceramics, pesticides and additives for oil and fuels. Barium sulfate is used by medical doctors for medical tests and X-ray photography. There is limited quantitative information regarding the extent of barium absorption following inhalation, oral or dermal exposure; however, as with many other metals, barium is probably very poorly absorbed from the gastrointestinal tract.

Occupational studies of workers exposed to barium dust have shown that workers have developed "baritosis". Affected workers did not show any clinical symptoms except a significantly higher incidence of hypertension (i.e., high blood pressure). The most commonly observed cardiovascular effects in cases of acute ingestion of barium compounds are hypertension and abnormalities in heart rhythm, while respiratory weakness and paralysis is observed in cases of acute ingestion of barium salts by humans. Acute exposure in rats indicates a lethal dose (LD_{50}) of 132 mg/kg-d for adult rats and 220 mg/kg-d for weanlings.

The EPA has set an RfD of 0.05 mg/kg-d for chronic oral exposures. Confidence in the oral RfD is medium. Increases in blood pressure have been observed as a critical effect in oral exposure studies. An inhalation RfD of 1E-04 mg/kg-d was derived by the EPA based on a short-term reproductive study in rats. This RfD is under review and subject to change as indicated in HEAST. There are no reliable data at present regarding the carcinogenicity of barium.

BERYLLIUM

Beryllium occurs in nature in rocks, soils and volcanic dust. It does not occur in its elemental form naturally. Beryllium compounds vary in water solubility. A major portion of beryllium will bind to soil and is not likely to migrate deeper into the ground and groundwater. The primary exposure routes for beryllium are inhalation and ingestion. The dermal route is a minor one. Most ingested beryllium (>99%) is excreted. Inhaled beryllium that enters the lungs remain there for an extended period of time (months to years). Lung and bone cancer are the most common cancers associated with beryllium exposure.

The EPA has set an oral RfD of 5E-03 mg/kg-d (IRIS) for exposure to beryllium. There are no toxic effects reported for the reference dose. Beryllium is a B2 (probable) human carcinogen. The human epidemiology studies are considered inadequate. The oral SF for beryllium is 4.3E+00 $(mg/kg-d)^{-1}$ (IRIS) based on water ingestion, and the inhalation SF is 8.4E+00 $(mg/kg-d)^{-1}$ (IRIS). Both slope factors were derived from experimental animal exposures to beryllium sulfate and other beryllium compounds.

CHROMIUM

Elemental chromium does not exist naturally in the environment, but is found primarily as a part of chromite ore. In compounds, this element exists in one of three valence states, +2, +3, or +6. The trivalent form is an essential human micronutrient involved in carbohydrate metabolism. Adverse effects have not been associated with the trivalent form. The hexavalent form is important industrially (typically in the form of chromates) and has been associated with serious toxicities. Human toxicity has been associated with hexavalent chromium by all routes of exposure. Long term exposure to airborne hexavalent chromium higher than natural background levels is known to produce lung and respiratory tract cancer in humans.

The EPA has determined the oral RfD for hexavalent chromium as 5E-03 mg/kg-d (IRIS) based on a drinking water study in rats. Hexavalent chromium is classified by EPA as a known human carcinogen (weight-of-evidence classification is Group A) by inhalation exposure. The inhalation SF is 4.1E+01 $(mg/kg-d)^{-1}$. No evidence exists to indicate that chromium is carcinogenic by the oral route.

LEAD

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It is widely distributed in the environment, and can be transported to long distances. Anthropogenic sources of lead come from gasoline additives, various metal products, ammunitions, paint, and storage batteries. The largest source of lead in air is from automobile exhaust. Children and pregnant women are the most sensitive subpopulations to chronic effects from lead exposure. The effects of lead exposure in children are reported as a decrease in IQ, neurological effects, including changes in brain function (encephalopathy) which may progress to coma. Transplacental transfer of lead from mother to fetus in humans, resulting in nervous system damage or changes, have also been reported in humans. Exposure to lead has also been linked to carcinogenic effects in laboratory animals.

The EPA has classified lead as a Group B2 carcinogen (i.e., probable human carcinogen). Although the agency has not derived a toxicity factor for lead, a range of 500-1,000 mg/kg of lead in soil has been determined by the EPA as being protective of sensitive populations.

MANGANESE

Manganese compounds occur naturally in rock. Manganese is found in living organisms as a cofactor in cholesterol and fatty acid synthesis. Exposure can occur by inhalation and ingestion. The dermal exposure route is negligible. Manganese absorption from soil exposures has not been investigated. It is important to note manganese is an important element in human nutrition. However, overexposure to manganese in humans via inhalation has been associated with "manganism" (i.e., a permanent brain damage which results in mental disturbances and impaired body movements). Other reported adverse effects of exposure to high concentrations of this metal are lung irritation, pneumonia, and impotence.

The EPA has set an oral RfD of 1E-01 mg/kg-d for oral exposure based on a total dietary intake and the critical effects of psychomotor disturbances. The inhalation RfD is 1E-04 mg/kg-d based on critical effects of increased prevalence of respiratory symptoms, and psychomotor disturbances.

VANADIUM

Vanadium is a metal found in compounds that are widely distributed at low concentrations in the earth's crust. Elemental vanadium does not occur in nature, but is associated with over 50 different mineral ores and in fossil fuels. Vanadium replaces other metals such as iron, titanium and aluminum in crystal structures. The only significant effect of vanadium exposure in human is mild to moderate respiratory distress, and mucosal irritation from exposure to vanadium dust. Workers exposed to vanadium through inhalation may develop coughs, chest pain, sore throat or eye irritation that can last for several days, following the exposure. These effects are not specific to pure vanadium but are equally associated with other vanadium chemical forms, following inhalation exposure.

The EPA has set an oral RfD of 0.007 mg/kg-d for chronic exposure via drinking water ingestion. An assessment of carcinogenic potential in humans can not be made at present because of the inadequacy of human and animal data.

BENZO(a)PYRENE

Benzo(a)pyrene of B(a)P is a chemical substance, formed as a result of the incomplete combustion of fossil fuel, garbage, or any organic matter, which is carried into the air on dust particles, and also distributed into water, soil, and on crops. B(a)P is a polycyclic aromatic hydrocarbon (PAH) and is found in products that contain creosote-treated wood materials, asphalt roads, and coal tar. Environmental exposures to this compound also include home heating with wood and coal, vehicle exhaust fumes, wildfires and agricultural burning.

B(a)P is readily absorbed via all exposure routes, rapidly distributed to several tissues, and is eliminated in the feces, regardless of the route of administration. Because of the "first pass" metabolic activity that occurs in the liver, orally administered B(a)P would be expected to show an enhanced rate of excretion relative to other routes of administration. The

metabolites of B(a)P are subject to enterohepatic (i.e., intestinal and liver) circulation as demonstrated in time-dependent increases in the intestinal tissue concentrations of intermediate compounds.

Available reports on non-carcinogenic systemic effects of B(a)P in humans indicate a variety of skin lesions and bronchitis, following occupational exposures to complex mixtures of PAH compounds. however, it is not possible to determine from these studies the specific toxic effects associated with individual PAHs. In general, systemic toxicity associated with B(a)P exposure is only evident at doses high enough to induce tumorigenicity in experimental animals.

Epidemiological studies have indicated an increased incidence of lung cancer in humans exposed to coke oven and roofing tar emissions, and to cigarette smoke. However, each of these mixtures contains B(a)P as well as carcinogenic PAHs, and other known carcinogens such as nitrosoamines. It is thus impossible to conclude from these studies that B(a)P is responsible for the carcinogenic effect. However, animal toxicological data have shown evidence of B(a)P carcinogenic potency in several bioassays involving many species, following administration by numerous routes. The reported tumor types include forestomach, squamous cell papillomas, and carcinomas. The EPA has classified B(a)P as a Group B2 carcinogen with and oral slope factor (SF) of 7.13 $(mg/kg-d)^{-1}$. The factor is derived from the geometric mean of a range of SFs (i.e., 4.5 to 11.7 mg/kg-d), and is based on an animal study that indicated squamous cell carcinoma of the forestomach, following exposure in the diet to B(a)P of unknown purity.

Table B-1a. Summary of Carcinogenic (Radioactive) Toxicity Information
for Contaminants of Potential Concern at the 100-HR-1 Operable Unit.

Contaminant	Weight of Evidence Clasification	Type of Cancer	Oral SF^a (pCi)$^{-1}$	Inhalation SF^a(pCi)$^{-1}$	External SF^a (pCi-yr/g)$^{-1}$	Half-life (years)
Americium-241	A	-	2.4E-10	3.2E-08	4.9E-09	4.3E+02
Cesium-134	A	-	4.1E-11	2.8E-11	5.2E-06	2.1E+00
Cesium-137	A	-	2.8E-11	1.9E-11	2.0E-06	3.0E+01
Cobalt-60	A	-	1.5E-11	1.5E-10	8.6E-06	5.3E+00
Europium-152	A	-	2.1E-12	1.1E-10	3.6E-06	1.4E+01
Europium-154	A	-	3.0E-12	1.4E-10	4.1E-06	8.8E+00
Europium-155	A	-	4.5E-13	1.8E-11	5.9E-08	5.0E+00
Nickel-63	A	-	9.1E-14	7.0E-13	-^{b}	1.0E+02
Plutonium-238	A	-	2.2E-10	3.9E-08	2.8E-11	8.8E+01
Plutonium-239/240	A	-	2.3E-10	3.8E-08	2.7E-11	6.6E+03
Potassium 40	A	-	1.1E-11	7.6E-12	5.4E-07	1.3E+09
Radium-226	A	bone	1.2E-10	3.0E-09	6.0E-06	1.6E+03
Strontium-90	A	-	3.6E-11	6.2E-11	-^{b}	2.9E+01
Thorium-228	A	-	5.5E-11	7.8E-08	5.6E-06	1.9E+00
Thorium-232	A	-	1.2E-11	2.8E-08	2.6E-11	1.4E+10
Uranium-233/234	A	-	1.6E-11	2.7E-08	4.2E-11	1.6E+05
Uranium-235	A	-	1.6E-11	2.5E-08	2.4E-07	7.0E+08
Uranium-238	A	-	2.8E-11	5.2E-08	3.6E-08	4.5E+09
Zirconium-95	A	-	9.9E-13	1.0E-11	2.5E-06	6.4E+01

^{a}Health Effects Summary Tables (HEAST, EPA 1992).
^{b}Not an external exposure hazard.
SF = Slope factor
- Not determined. The carcinogenic potential of these contaminants is based on the fact that they emit ionizing radiation. EPA does not cite direct epidemiological evidence linking these radionuclides with a particular form of cancer (56 FR 33050).

WHC-SD-EN-RA-004, Rev. 0

Table B-1b. Summary of Carcinogenic (Non-Radioactive) Toxicity Information for
Contaminants of Potential Concern at the 100-HR-1 Operable Unit.

Contaminant	Weight of Evidence Classification	Type of Cancer	Oral SF $(mg/kg-d)^{-1}$	Inhalation SF $(mg/kg-d)^{-1}$
arsenic	A	lung, skin	1.7E+00[a,b]	1.5E+01[c,d]
benzo(a)pyrene	B2	gross tissue tumors	7.3E+00[b]	_[e]
beryllium	B2	-	4.3+00[b]	8.4E+00[b]
chromium (VI)	A	lung	_[f]	4.1E+01[b]
lead	B2	ND	ND	ND

[a]Based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1993).
[b]Integrated Risk Information System (IRIS, EPA 1993).
[c]Health Effects Assessment Summary Tables (HEAST, EPA 1992).
[d]Based on 30% absorption of inhaled arsenic.
[e]Under evaluation by the Office of Health Effects Assessments.
[f]Not considered to be a carcinogen or not carcinogenic by this exposure route.
- = Not applicable.
ND = Not determined.

Table B-2. Summary of Systemic Toxicity Information for Contaminants of Potential Concern at the 100-HR-1 Operable Unit.

Contaminant	Oral RfD mg/kg-d	Oral RfD[a,b] (basis/source)	Confidence Level[c]	Critical Effect	Uncertainty Factors	Modifying Factors	Inhalation RfD mg/kg-d	Inhalation RfD[a,b] (basis/source)	Confidence Level[c]	Critical Effect	Uncertainty Factors	Modifying Factors
INORGANICS												
Arsenic	3.0E-04	water/IRIS	M	hyperpigmen tation, keratosis	3	1	ND	--	--	--	--	--
Barium	7.0E-02	water/IRIS	M	increased blood pressure	3	1	1E-4	HEAST	--	reproductive effects	1000	--
Beryllium	5.0E-03	water/IRIS	L	none observed	100	1	ND	--	--	--	--	--
Chromium (VI)	5.0E-03	water/IRIS	L	none observed	500	1	ND	--	--	--	--	--
Lead	ND	--	--	--	--	--	ND	--	--	--	--	--
Manganese	1.4E-01 5.0E-03	food/IRIS water/IRIS	M	CNS effect	1	1	1.1E-04	air/IRIS	M	resp. symptoms, psychomotor disturbances	300	3
Vanadium	7.0E-03	water/HEAST	--	none observed	100	--	ND	--	--	--	--	--
ORGANICS												
Benzo(a)pyrene	ND	--	--	--	--	--	ND	--	--	--	--	--

[a]Integrated Risk Information System (IRIS, EPA 1993).
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1992).
[c]L = Low.
 M = Medium.
 H = High.
RfD = Reference Dose.
ND = Not determined.
-- = Not applicable.

APPENDIX C

EXAMPLE CALCULATIONS

References:

DOE-RL, 1993a, *Hanford Site Baseline Risk Assessment, Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland, Washington.

Dorian, J.J., and V.R. Richards, 1978, *Radiological Characterization of the Retired 100 Areas*, UNI-946, United Nuclear Industries, Richland, Washington.

EPA, 1989a, *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part A, Interim Final*, EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1992, *Health Effects Assessment Summary Tables: Annual FY-1992*, OHEA/ECAD-UN-821, March 1992, U.S. Environmental Protection Agency, Office of Energy and Remedial Response, Washington, D.C.

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX C

FREQUENT-USE AND OCCASIONAL-USE SCENARIOS RISK ASSESSMENT SAMPLE CALCULATIONS

This appendix presents the radiosotope decay calculations, the exposure assumptions and equations used to generate the preliminary risk-based screening, intake, risk assessment, and risk-based concentrations tables for this qualitative risk assessment. Tables are presented in Chapter 3.0 and Appendix E. All calculations presented in this appendix are presented as examples only. The concentrations of contaminants do not necessarily correspond to any specific high-priority waste site for this operable unit.

C-1.0 RADIOISOTOPE DECAY CALCULATIONS

The maximum concentrations of radioisotopes in the historical (Dorian and Richards 1978) and the current LFI data are decayed to 1992 and 2018 using the specific radioisotope half-lifes (HEAST, EPA 1992) and the following calucations:

$$\alpha_t = \alpha_o \ (0.5)^{t/T \ 1/2} \hspace{3cm} \text{C-1}$$

where:

α_t = concentration/activity remaining after a time interval, t
α_o = initial concentration/acitvity
t = elapsed time
T1/2 = half-life of subject radionuclide

Example Calculation:

Cesium-134 - half life = 2.1 years
Concentration in 1976 sampling data = 100 pCi/g
Elapsed time = 16 years (1976-1992)
Concentration in 1992 (αt) = 100 pCi/g $(0.5)^{16 \ y/2.1 \ y}$ = 0.51 pCi/g

C-2.0 PRELIMINARY RISK-BASED SCREENING

As recommended in the HSBRAM (DOE-RL 1993a), all preliminary risk-based benchmark screening concentrations are calculated using residential exposure assumptions. The calculation of the preliminary risk-based benchmark concentrations considers both noncarcinogenic effects (i.e., systemic toxicity) and carcinogenic effects. Risk-based benchmark concentrations are calculated for soil concentrations that would be equivalent to exposures at a hazard quotient (HQ) of 0.1 for contaminants with noncarcinogenic effects. An incremental lifetime cancer risk (ICR) of 1E-07 is used for contaminants with carcinogenic effects. Screenings are performed for the ingestion, fugitive dust inhalation, inhalation of volatile contaminants from soil, and external exposure pathways.

For carcinogenic non-radioactive contaminants, the general equation to calculate ingestion or inhalation risk-based concentrations is:

$$C = \frac{TR \times BW \times AT \times CF}{SF \times IR \times EF \times ED} \qquad\qquad \text{C-2}$$

where:

C	=	risk-based benchmark concentration (mg/kg)
TR	=	target excess individual lifetime cancer risk (1E-07)
BW	=	body weight (kg)
AT	=	averaging time (365 d/yr x 70 yr)
SF	=	contaminant-specific slope factor $(mg/kg\text{-}d)^{-1}$
IR	=	intake rate (mg/d or m^3/d for soil or air, respectively)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (as appropriate)

For radioactive contaminants, the general equation to calculate risk-based screening concentration is:

$$C = \frac{TR \times CF}{SF \times IR \times EF \times ED} \qquad\qquad \text{C-3}$$

where:

C	=	risk-based concentration (pCi/g)
TR	=	target excess individual lifetime cancer risk (1E-07)
SF	=	radionuclide-specific slope factor [$(pCi\text{-}yr/g)^{-1}$ or $(pCi)^{-1}$ for external or ingestion/inhalation, respectively]
IR	=	contact rate (variable)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (as appropriate)

The equation above may also be used to evaluate external exposures. In this case, the "intake" has units of pCi-yr/g and represents the time a receptor is in close proximity to a particular radionuclide soil concentration. The "contact rate" is determined as follows:

$$IR_{ext} = ET \times RF \times CF_2 \qquad\qquad C-4$$

where:

IR_{ext} = external exposure contract rate (yr/d)
ET = exposure time (hr/d)
CF_2 = conversion factor (1.14E-04 yr/hr)

The external exposure contact rate is then used as the contact rate for Equation C-2.

For noncarcinogenic effects, the general equation to calculate risk based screening is:

$$C = \frac{THQ \times RfD \times BW \times AT \times CF}{IR \times EF \times ED} \qquad\qquad C-5$$

where:

C = risk-based benchmark concentration (mg/kg)
THQ = target hazard quotient (0.1)
RfD = contaminant-specific chronic reference dose (mg/kg-d)
BW = body weight (kg)
AT = averaging time (365 d/yr x ED in yr)
IR = intake rate (mg/d or m^3/d for soil or air, respectively)
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
CF = conversion factor (as appropriate)

Risk-based benchmark concentrations are derived using residential exposure assumptions from the HSBRAM (DOE-RL 1993). These assumptions are listed in Table C-1.

C-2.1 SCREENING CALCULATIONS

The following equations provide the screening equations utilized for the evaluation of the soil ingestion, fugitive dust inhalation, inhalation of volatile contaminants from soil, and external exposure routes and reduce the standard default factors to a single factor.

Table C-1. Preliminary Risk-based Screening Exposure Assumptions[a]

	Ingestion			Inhalation			External
	Carcinogenic Non-Radioactive	Carcinogenic Radioactive	Noncarcinogenic	Carcinogenic Non-Radioactive	Carcinogenic Radioactive	Noncarcinogenic	Carcinogenic Radioactive
Averaging Time (AT)	365 d/yr x 70 yr	NA	365 d/yr x 6 yr	365 d/yr x 70 yr	NA	365 d/yr x 6 yr	NA
Body Weight (BW)	Adult: 70 Kg Child: 16 Kg	NA	16 Kg	70 Kg	NA	16 Kg	NA
Contaminant-Specific Slope Factor (SF)	Contaminant-Specific	Contaminant-Specific	NA	Contaminant-Specific	Contaminant-Specific	NA	Contaminant-Specific
Contaminant-Specific Chronic Reference Dose (RfD)	NA	NA	Contaminant-Specific	NA	NA	Contaminant Specific	NA
Conversion Factor (CF)	1E+06 mg/kg	1E+03 mg/g	1E+06 mg/kg	NA	1E-03 kg/g	NA	NA
Exposure Duration (ED) - Soil/Air	Adult: 24 yr Child: 6 yr	Adult: 24 yr Child: 6 yr	6 yr	30 yr	30 yr	6 yr	30 yr
Exposure Frequency (EF)	365 d/yr	365 d/yr	365 d/yr	365 d/yr	365 d/yr	365 d/yr	365 d/yr
Intake Rate (IR) - Soil/Air	Adult: 100 mg/d Child: 200 mg/d	Adult: 100 mg/d Child: 200 mg/d	200 mg/d	20 m³/d	20 m³/d	10 m³/d	2.7E-03 yr/d
Soil to Air Respirable Factor (PEF)	NA	NA	NA	2E+07 m³/kg	2E+07 m³/kg	2E+07 m³/kg	NA
Target Hazard Quotient (THQ)	NA	NA	1E-01	NA	NA	1E-01	NA
Target Excess Lifetime Individual Cancer Risk (TR)	1E-07	1E-07	NA	1E-07	1E-07	NA	1E-07

NA - Not Applicable
[a]Based on HSBRAM (DOE-RL 1993a)

WHC-SD-EN-RA-004, Rev. 0

C-2.1.1 Soil Ingestion

<u>Carcinogenic - Non-Radioactive</u>

$$C = \frac{TR \times AT \times CF}{SF \times \left[\left(\dfrac{IR \times EF \times ED}{BW}\right)_{Child} + \left(\dfrac{IR \times EF \times ED}{BW}\right)_{Adult}\right]}$$

$$C\ (mg/kg) = \frac{(1E{-}07)(365\ d/yr \times 70\ yr)(1E{+}06\ mg/kg)}{SF\ (mg/kg{-}d)^{-1}\left[\left(\dfrac{(200\ mg/d)(365\ d/yr)(6\ yr)}{16\ kg}\right)_{Child} + \left(\dfrac{(100\ mg/d)(365\ d/yr)(24\ yr)}{70\ kg}\right)_{Adult}\right]}$$

$$C\ (mg/kg) = \frac{6.4E{-}02\ d}{SF\ (mg/kg{-}d)^{-1}} \qquad \textbf{C-6}$$

<u>Carcinogenic - Radioactive</u>

$$C = \frac{TR \times CF}{SF \times \left[(IR \times EF \times ED)_{Child} + (IR \times EF \times ED)_{Adult}\right]}$$

$$C\ (pCi/g) = \frac{(1E{-}07)(1E{+}03\ mg/g)}{SF\ (pCi)^{-1}\left[(200\ mg/d)(365\ d/yr)(6\ yr)_{Child} + (100\ mg/d)(365\ d/yr)(24\ yr)_{Adult}\right]}$$

$$C\ (pCi/g) = \frac{7.6E{-}11\ (g)^{-1}}{SF\ (pCi)^{-1}} \qquad \textbf{C-7}$$

Noncarcinogenic

$$C = \frac{THQ \times RfD \times BW \times AT \times CF}{IR \times EF \times ED}$$

$$C \ (mg/kg) = \frac{(0.1)(RfD \ mg/kg-d)(16 \ kg)(365 \ d/yr \times 6 \ yr)(1E+06 \ mg/kg)}{(200 \ mg/d)(365 \ d/yr)(6 \ yr)} \qquad C-8$$

$$C \ (mg/kg) = RfD \ (mg/kg-d) \times 8.0E+03 \ d$$

C-2.1.2 Inhalation

For the inhalation pathway, screening values are generated for the inhalation of fugitive dust (Section C-2.1.2.1). The respirable particulate factor (PEF) of 2E+07 m³/kg used in the calculation is based on the National Primary Ambient Air Quality Standard for particulate matter of 50 μg/m³ and the assumption that 100% of the particulates are retained in the lungs and absorbed. The following equation uses the National Primary Ambient Air Quality Standard for particulate matter and the appropriate coversion factor:

$$PEF = AQS \times CF$$
$$= \frac{1}{50 \ \mu g/m^3} \times (1E+09) \ \mu g/kg \qquad C-9$$
$$= 2E+07 \ m^3/kg$$

Because the qualitative nature of the assessment, there is no site-specific PEF value. All risk based screening and risk assessment calculations use a PEF of 2E+07 m³/kg.

The risk-based screening for inhalation of volatile contaminants from soil (Section C-2.1.2.2) uses contaminant-specific and site-specific information to calculate a volatilization factor (VF).

C-2.1.2.1 Inhalation of Fugitive Dust

<u>Carcinogenic - Non-Radioactive</u>

$$C = \frac{TR \times BW \times AT \times PEF}{SF \times IR \times EF \times ED}$$

$$C \text{ (mg/kg)} = \frac{(1E-07)(70 \text{ kg})(365 \text{ d/yr} \times 70 \text{ yr})(2E+07 \text{ m}^3/\text{kg})}{SF \text{ (mg/kg-d)}^{-1}(20 \text{ m}^3/\text{d})(365 \text{ d/yr})(30 \text{ yr})} \qquad \text{C-10}$$

$$C \text{ (mg/kg)} = \frac{1.6E+01 \text{ d}}{SF(\text{mg/kg-d})^{-1}}$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

<u>Carcinogenic - Radioactive</u>

$$C = \frac{TR \times PEF \times CF}{SF \times IR \times EF \times ED}$$

$$C \text{ (pCi/g)} = \frac{(1E-07)(2E+07 \text{ m}^3/\text{kg})(1E-03 \text{ kg/g})}{SF \text{ (pCi)}^{-1}(20 \text{ m}^3/\text{d})(365 \text{ d/yr})(30 \text{ yr})} \qquad \text{C-11}$$

$$C \text{ (pCi/g)} = \frac{9.1E-09 \text{ (g)}^{-1}}{SF(\text{pCi})^{-1}}$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

Noncarcinogenic

$$C = \frac{THQ \times RfD \times BW \times AT \times PEF}{IR \times EF \times ED}$$

$$C \; (mg/kg) = \frac{(0.1)(RfD \; mg/kg{-}d)(16 \; kg)(365 \; d/yr \times 6 \; yr)(2E{+}07 \; m^3/kg)}{(10 \; m^3/d)(365 \; d/yr)(6 \; yr)} \qquad \text{C-12}$$

$$C \; (mg/kg) = RfD \; (mg/kg{-}d) \times 3.2E{+}06 \; d$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

C-2.1.2.2 Inhalation of Volatile Contaminants from Soil

Carcinogenic - Non-Radioactive

$$C = \frac{TR \times BW \times AT \times VF}{SF \times IR \times EF \times ED}$$

$$C \; (mg/kg) = \frac{(1E{-}07)(70 \; kg)(365 \; d/yr \times 70 \; yr) \; (VF \; m^3/kg)}{SF \; (mg/kg{-}d)^{-1}(20 \; m^3/d)(365 \; d/yr)(30 \; yr)} \qquad \text{C-13}$$

$$C \; (mg/kg) = \frac{(8.16E{-}07 \; kg{-}d/m^3)(VF \; m^3/kg)}{SF(mg/kg{-}d)^{-1}}$$

Note: VF is a contaminant specific, soil-to-air volatilization factor. Derivation of a VF is provided below.

Carcinogenic - Radioactive

Not applicable.

Noncarcinogenic

$$C = \frac{THQ \times RfD \times BW \times AT \times VF}{IR \times EF \times ED}$$

$$C \ (mg/kg) = \frac{(0.1)(RfD \ mg/kg-d)(16 \ kg)(365 \ d/yr \times 6 \ yr)(VF \ m^3/kg)}{(10 \ m^3/d)(365 \ d/yr)(6 \ yr)} \quad \text{C-14}$$

$$C \ (mg/kg) = (1.6E-01 \ kg-d/m^3)(RfD \ mg/kg-d)(VF \ m^3/kg)$$

Note: VF is a contaminant specific, soil to air volatilization factor. Derivation of a VF is provided as follows:

$$VF \ (m^3/kg) = \frac{LS \times V \times MH}{A} \cdot \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times E \times K_{as} \times CF)} \quad \text{C-15}$$

$$\text{Where:} \quad \alpha(cm^2/s) = \frac{D_{ei} \times E}{E + (p_s)(1-E)/K_{as}} \quad \text{C-16}$$

where
LS	=	width of contaminated area (m)
V	=	site-specific wind speed in mixing zone (m/s)
MH	=	mixing height (2 m)
A	=	area of contamination (cm^2)
D_{ei}	=	effective diffusivity [$D_i \times E^{.33}$]
E	=	soil porosity (unitless)
K_{as}	=	soil/air partition coefficient [$(H/K_d) \times 41$] (g soil/cm^3) where 41 is a units conversion factor
P_s	=	true soil density (g/cm^3)
T	=	exposure interval (s)
OC	=	organic carbon content of soil (unitless)
D_i	=	molecular diffusivity (cm^2/s)
H	=	Henry's law constant (atm-m^3/mol)
K_d	=	soil-water partition coefficient [$K_{oc} \times OC$ (cm^3/g)]
K_{oc}	=	organic-carbon partition coefficient (cm^3/g)
CF	=	conversion factor (0.001 kg/g)

C-2.1.2 External Exposure

External pathways apply exclusively to radioactive contaminants, which are evaluated only for their carcinogenic potential.

$$C = \frac{TR}{SF \times IR \times EF \times ED}$$

$$C\ (pCi/g) = \frac{1E-07}{SF\ (pCi-yr/g)^{-1}(2.7E-03\ yr/d)(365\ d/yr)(30\ yr)} \qquad \text{C-17}$$

$$C\ (pCi/g) = \frac{3.4E-09(yr)^{-1}}{SF\ (pCi-yr/g)^{-1}}$$

C-2.2 EXAMPLE CALCULATIONS

Example calculations are provided below for risk-based screening concentrations for soil ingestion, inhalation of fugitive dust, and external exposure. Different non-radioactive contaminants are used in the examples because no single contaminant was identified that had all inhalation and ingestion slope factors and RfDs. Uranium-238 is used for the radioactive contaminant examples.

C-2.2.1 Soil Ingestion

Carcinogenic - Non-Radioactive - Arsenic

$$C = \frac{6.4E-02\ d}{1.7(mg/kg-d)^{-1}} = 0.038\ mg/kg \qquad \text{C-18}$$

Carcinogenic - Radioactive - Uranium-238

$$C = \frac{7.6E-11(g)^{-1}}{2.8E-11(pCi)^{-1}} = 2.7\ pCi/g \qquad \text{C-19}$$

Noncarcinogenic - Arsenic

$$C = 3E-04\ mg/kg-d \times 8.0E+03\ d = 2.4\ mg/kg \qquad \text{C-20}$$

C-2.2.2 Inhalation of Fugitive Dust

<u>Carcinogenic - Non-Radioactive</u> - Arsenic

$$C = \frac{1.6E+01\ d}{50\ (mg/kg-d)^{-1}(0.3)^*} = 1.1\ mg/kg \qquad \text{C-21}$$

* The SF is modified based on the assumption that 30% of inhaled arsenic is absorbed.

<u>Carcinogenic - Radioactive</u> - Uranium-238

$$C = \frac{9.1E-09(g)^{-1}}{5.2E-08(pCi)^{-1}} = 1.8E-01\ pCi/g \qquad \text{C-22}$$

<u>Noncarcinogenic</u> - Mercury

$$C = 8.6E-05\ mg/kg-d \times 3.2E+06\ d = 2.8E+02\ mg/kg \qquad \text{C-23}$$

C-2.2.3 Inhalation of Volatile Contaminants from Soil

<u>Carcinogenic</u> - <u>Non Radioactive</u> Methylene Chloride

$$VF\ (mg^3/kg) = \frac{LS \times V \times MH}{A} \cdot \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times E \times K_{as} \times CF)}$$

C-24

$$\text{Where:} \qquad \alpha(cm^2/s) = \frac{D_{ei} \times E}{E + (p_s)(1-E)/K_{as}}$$

and

LS	=	width of contaminated area (76.2 m)
V	=	site-specific wind speed in mixing zone (3.3 m/s)
MH	=	mixing height (2 m)
A	=	area of contamination (46,482,000 cm^2)
D_{ei}	=	effective diffusivity for methylene chloride ($D_i \times 0.25^{.33}$) = 6.8E-02 cm^2/s
E	=	soil porosity (0.25)
K_{as}	=	soil/air partition coefficient for methylene chloride (H/K_d) x 41 = 9.3E-01 g/ soil/cm^3 air
p_s	=	true soil density (2.7 g/cm^3)
T	=	exposure interval (9.5E + 08 s)
OC	=	organic carbon content of soil (0.01)

D_i = molecular diffusivity of methylene chloride at 30°C (1.1E-01 cm²/s)

H = Henry's law constant for methylene chloride (2E-03 atm-m³/mol)

K_d = soil-water partition coefficient for methylene chloride (K_{oc} x OC = 8.8E-02 cm³/g)

K_{oc} = organic-carbon partition coefficient (8.8E+00 cm³/g)

CF = conversion factor (0.001 kg/g)

$$VF(m^3/kg) =$$

$$\frac{76.2 \times 3.3 \times 2}{46,482,000} \cdot \frac{(3.14 \times \alpha \times 9.5E{+}08)^{\frac{1}{2}}}{\left(2 \times (0.11 \times 0.25^{.33}) \times 0.25 \times \left[\left(\frac{0.002}{8.8 \times 0.01}\right) \times 41\right] \times 0.001\right)} \qquad \text{C-25}$$

$$\text{where:} \quad \alpha \ (cm^2/s) = \frac{(0.11 \times 0.25^{.33}) \times 0.25}{0.25 + \left(\frac{(2.7)(1{-}0.25)}{\left(\frac{0.002}{8.8 \times 0.01}\right) \times 41}\right)} = 7.0E{-}03 \ cm^2/s \qquad \text{C-26}$$

$$VF = \text{methylene chloride} = 1.6E{+}03 \ m^3/kg$$

Therefore:

$$C = \frac{(8.16E{-}07 \ kg{-}d/m^3) \ (1.6E{+}03 \ m^3/kg)}{1.6E{-}03(mg/kg{-}d)^{-1}} \qquad \text{C-27}$$

$$= 0.82 \ mg/kg$$

Carcinogenic - Radioactive

Not applicable.

Non-Carcinogenic - 2-butanone

$$VF \ (m^3/kg) = \frac{LS \times V \times MH}{A} \cdot \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times E \times K_{as} \times CF)} \qquad \text{C-28}$$

$$\text{Where:} \qquad \alpha(cm^2/s) = \frac{D_{ei} \times E}{E + (p_s)(1-E)/K_{as}} \qquad \text{C-29}$$

and

LS	=	width of contaminated area (76.2 m)
V	=	site-specific wind speed in mixing zone (3.3 m/s)
MH	=	mixing height (2 m)
A	=	area of contamination (46,482,000 cm^2)
D_{ei}	=	effective diffusivity for 2-butanone ($D_i \times 0.25^{.33}$) = 6.0E-02 cm^2/s
E	=	soil porosity (0.25)
K_{as}	=	soil/air partition coefficient for 2-butanone (H/K_d) x 41 = 2.5E-02 g soil/cm^3 air
p_s	=	true soil density (2.7 g/cm^3)
T	=	exposure interval (9.5E+08 s)
OC	=	organic carbon content of soil (0.01)
D_i	=	molecular diffusivity of 2-butanone at 30°C (9.5E-02 cm^2/s)
H	=	Henry's law constant for 2-butanone (2.7E-05 atm-m^3/mol)
K_d	=	soil-water partition coefficient for 2-butanone (K_{oc} x OC = 4.5E-02 cm^3/g)
K_{oc}	=	organic-carbon partition coefficient (4.5E+00 cm^3/g)
CF	=	conversion factor (0.001 kg/g)

$$VF(m^3/kg) = \frac{76.2 \times 3.3 \times 2}{46,482,000} \cdot$$

<div align="right">C-30</div>

$$\frac{(3.14 \times \alpha \times 9.5E+08)^{\frac{1}{2}}}{\left[2 \times (9.5E-02 \times 0.25^{33}) \times 0.25 \times \left[\left(\frac{2.7E-05}{4.5E+00 \times 0.01}\right) \times 41\right] \times 0.001\right]}$$

where: $\alpha \, (cm^2/s) = \dfrac{(9.5E-02 \times 0.25^{33}) \times 0.25}{0.25 + \left(\dfrac{(2.7)(1-0.25)}{\left(\dfrac{2.7E-05}{4.5E+00 \times 0.01}\right) \times 41}\right)} = 1.8E-04 \, cm^2/s$

<div align="right">C-31</div>

$$VF = 2\text{-butanone} = 1.07E\text{-}04 \, m^3/kg$$

Therefore:

$$C = (1.6E-01 \, kg\text{-}d/m^3)(2.9E-01 \, mg/kg\text{-}d)(1.07E+04 \, m^3/kg)$$

<div align="right">C-32</div>

$$= 1.5E+02 \, mg/kg$$

C-2.2.4 External Exposure - Uranium-238

$$C = \frac{3.4E-09 \, (yr)^{-1}}{3.6E-08 \, (pCi\text{-}yr/g)^{-1}} = 0.094 \, pCi/g$$

<div align="right">C-33</div>

C-2.3 SCREENING PROCESS

The screening calculations above, determine the preliminary risk-based benchmark concentrations in soil (screening concentrations) for the contaminants. If the maximum concentration measured at a waste site, exceeds this screening concentration for any one of the ingestion, inhalation or external pathways, it is considered a contaminant of potential concern for that waste site. The remainder of this appendix is devoted to calculations used to assess potential risk due to exposure to the contaminants of potential concern.

C-3.0 CALCULATION OF CONTAMINANT INTAKES (RISK CHARACTERIZATION WHEN LFI DATA ARE AVAILABLE)

Standard EPA equations for calculation of intakes, as provided in the Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A. (RAGS, EPA 1989a) and the HSBRAM (DOE-RL 1993a), are used as the basis for all intake calculations.

Calculation of Non-radioactive Contaminant Intakes. The basic equation for calculating intakes of non-radioactive contaminants via soil ingestion or inhalation of soil contaminants is:

$$\text{Intake} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT \times OF} \qquad \text{C-34}$$

where:

Intake	=	chronic daily intake of the contaminant (mg/kg-d)
C	=	contaminant concentration in the medium (mg/kg)
IR	=	contact rate (mg/d or m^3/d)
ED	=	exposure duration (yr)
EF	=	exposure frequency (d/yr)
CF	=	conversion factor (as appropriate)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)
OF	=	Other factor, as appropriate (e.g., PEF, VF)

Calculation of Radioactive Contaminant Intakes. The quantification of exposures to radioactive contaminants requires a separate treatment, as the units used to express environmental concentrations of radioactive and non-radioactive contaminants are different. In addition, intake estimates for radionuclides should not be divided by body weight or averaging time. Instead, the calculated intakes for radioactive contaminants represent radionuclide activities that are inhaled or ingested over a lifetime.

The basic equation for calculating intakes of radioactive contaminants via soil ingestion or inhalation of soil contaminants is:

$$\text{Intake} = \frac{C \times IR \times EF \times ED \times CF_1}{OF} \qquad \text{C-35}$$

where:

Intake	=	radionuclide-specific lifetime intake (pCi)
C	=	radionuclide concentration in the medium (pCi/g)
IR	=	contact rate (e.g., mg/d or m^3/d)
EF	=	exposure frequency (d/yr)

ED = exposure duration (yr)
CF$_1$ = conversion factor (as appropriate)
OF = Other factor, as appropriate (e.g., PEF)

Equation C-33 may also be used to evaluate external exposures. In this case, the "intake" has units of pCi-yr/g, and represents the time a receptor is in close proximity to a particular radionuclide soil concentration. The "contact rate" is determined as follows:

$$IR_{ext} = ET \times RF \times CF_2 \qquad \textbf{C-36}$$

where:

IR$_{ext}$ = external exposure contact rate (yr/d)
ET = exposure time (hr/d)
RF = dose reduction factor (0.8, unitless)
CF$_2$ = conversion factor (1.14E-04 yr/hr)

The external exposure contact rate is then used as the contact rate of equation C-33. A dose reduction factor is used to obtain a more realistic estimate of external exposure by taking into account the effects of time spent indoors shielding while indoors and ground roughness. A factor of 0.8 is recommended by HSBRAM (DOE-RL 1993a).

C-3.1 INTAKE CALCULATIONS

The following subsections present example intake calculations for the ingestion, inhalation of fugitive dust, inhalation of volatile soil contaminant and external pathways and reduce the standard default factors to a single factor. Since the intake equations do not vary from those presented in Section C-2.0, the calculations are performed directly. All examples are presented for the frequent-use scenario. Occasional-use intakes are calculated using the same equations with parameters for the occasional-use scenario appropriately substituted. Exposure parameters for the frequent-use scenario are based on residential exposure parameters and for the occasional-use scenario are based on recreational exposure parameters. The exposure parameters are summarized in Table C-2.

C-3.1.1 Soil Ingestion - Residential

Carcinogenic - Non-Radioactive

Intake (mg/kg-d) =

$$\frac{C\ (mg/kg)\left[\dfrac{(200\ mg/d \times 365\ d/yr \times 6\ yr)}{(16\ kg)} + \dfrac{(100\ mg/d \times 365\ d/yr \times 24\ yr)}{(70\ kg)}\right]}{(365\ d/yr)(70\ yr)(1E+06\ mg/kg)} \qquad \textbf{C-37}$$

Intake = C (mg/kg) $\times$ 1.6E-06 d^{-1}

<u>Carcinogenic Radioactive</u>

$$\text{Intake (pCi)} = (C \text{ pCi/g})[(100 \text{ mg/d} \times 24 \text{ yr}) + (200 \text{ mg/d} \times 6 \text{ yr})](365 \text{ d/yr})(1E-03 \text{ g/mg})$$

$$\text{Intake} = C \text{ (pCi/g)} \times 1.3E+03 \text{ g} \qquad \textbf{C-38}$$

<u>Noncarcinogenic</u>

$$\text{Intake (mg/kg-d)} =$$

$$\frac{(C \text{ mg/kg})(200 \text{ mg/d})(365 \text{ d/yr})(6 \text{ yr})(1E-06 \text{ kg/mg})}{(16 \text{ kg})(6 \text{ yr} \times 365 \text{ d/yr})} \qquad \textbf{C-39}$$

$$\text{Intake} = C \text{ (mg/kg)} \times 1.3E-05 \text{ d}^{-1}$$

C-3.1.2 Inhalation of Fugitive Dust

Intakes for the inhalation of fugitive dust are calculated using the respirable particulate factor (PEF) of $2.0E+07$ m^3/kg. This value is based on the National Primary Ambient Air Quality Standard for particulate matter of 50 µg/m^3 and the assumption that 100% of the particulate is retained in the lungs and absorbed.

<u>Carcinogenic - Non-Radioactive</u>

$$\text{Intake (mg/kg-d)} =$$

$$\frac{(C \text{ mg/kg})(20 \text{ m}^3/\text{d})(365 \text{ d/yr})(30 \text{ yr})}{(70 \text{ kg})(70 \text{ yr} \times 365 \text{ d/yr})(2.0E+07 \text{ m}^3/\text{kg})} \qquad \textbf{C-40}$$

$$\text{Intake} = C \text{ (mg/kg)} \times 6E-09 \text{ d}^{-1}$$

Carcinogenic - Radioactive

$$\text{Intake (pCi)} =$$

$$\frac{(C \text{ pCi/g})(20 \text{ m}^3/\text{d})(365 \text{ d/yr})(30 \text{ yr})}{(2E+07 \text{ m}^3/\text{kg}) (1E-03 \text{ kg/g})} \qquad \textbf{C-41}$$

$$\text{Intake} = C \text{ (pCi)} \times 11 \text{ g}$$

Noncarcinogenic

$$\text{Intake (mg/kg-d)} =$$

$$\frac{(C \text{ mg/kg})(10 \text{ m}^3/\text{d})(365 \text{ d/yr})(6 \text{ yr})}{(16 \text{ kg})(6 \text{ yr} \times 365 \text{ d/yr}) (2E+07 \text{ m}^3/\text{kg})} \qquad \textbf{C-42}$$

$$\text{Intake} = C \text{ (mg/kg)} \times 3.2E-08 \text{ d}^{-1}$$

C-3.1.3 Inhalation of Volatile Soil Contaminants

None of the volatile soil contaminants failed the preliminary risk-based screening. Therefore, example calculations are not provided.

C-3.1.4 External Exposure - Uranium-238

$$\text{Intake} = (C \text{ pCi/g})(24 \text{ hr/d})(0.8)(1.14E-04 \text{ yr/hr})(365 \text{ d/yr})(30 \text{ yr}) \qquad \textbf{C-43}$$

$$\text{Intake} = C \text{ (pCi/g)} \times 2.4E+01 \text{ yr}$$

C-3.2 EXAMPLE CALCULATIONS

Example calculations are made using example concentrations for arsenic, mercury, and uranium-238. These concentrations are 1.2 mg/kg, 4.3 mg/kg and 1.3 pCi/g respectively.

C-3.2.1 Soil Ingestion

Carcinogenic - Non-Radioactive - Arsenic

$$\text{Intake} = 1.2 \text{ mg/kg} \times 1.6E-06 \text{ d}^{-1} = 1.9E-06 \text{ mg/kg-d} \qquad \textbf{C-44}$$

Carcinogenic - Radioactive - Uranium-238

$$\text{Intake} = 1.3 \text{ pCi/g} \times 1.3E+03 \text{ g} = 1.7E+03 \text{ pCi} \qquad \textbf{C-45}$$

<u>Noncarcinogenic</u> - Arsenic

$$\text{Intake} = 1.2 \text{ mg/kg} \times 1.3E\text{-}05 \text{ d}^{-1} = 1.6E\text{-}05 \text{ mg/kg-d} \qquad \text{C-46}$$

C-3.2.2 Inhalation of Fugitive Dust

<u>Carcinogenic - Non-Radioactive</u> - Arsenic

$$\text{Intake} = 1.2 \text{ mg/kg} \times 6E\text{-}09 \text{ d}^{-1} \times 0.30^* = 2.2E\text{-}09 \text{ mg/kg-d} \qquad \text{C-47}$$

*The SF is modified based on the assumption that 30% of inhaled arsenic is absorbed.

<u>Carcinogenic - Radioactive</u> - Uranium-238

$$\text{Intake} = 1.3 \text{ pCi/g} \times 11 \text{ g} = 14.3 \text{ pCi} \qquad \text{C-48}$$

<u>Noncarcinogenic</u> - Mercury

$$\text{Intake} = 4.3 \text{ mg/kg} \times 3.2E\text{-}08 \text{ d}^{-1} = 1.4E\text{-}07 \text{ mg/kg-d} \qquad \text{C-49}$$

C-3.2.3 External Exposure - Uranium-238

$$\text{Intake} = 1.3 \text{ pCi/g} \times 23 \text{ yr} = 29.9 \text{ pCi-yr/g} \qquad \text{C-50}$$

C-4.0 CALCULATION OF HUMAN HEALTH RISK ASSESSMENT

Lifetime Incremental Cancer Risk

The basic equation for determining the lifetime incremental cancer risk for the ingestion, inhalation and external exposure pathways is:

$$ICR = I \times SF \qquad \text{C-51}$$

where:

ICR	=	lifetime incremental cancer risk (unitless)
I	=	intake (mg/kg-d)
SF	=	contaminant-specific slope factor $(mg/kg\text{-}d)^{-1}$

Hazard Quotient

The basic equation for determining the hazard quotient for the ingestion and inhalation pathways is:

$$HQ = I/RfD \qquad \text{C-52}$$

where:

HQ	=	hazard quotient (unitless)
I	=	intake (mg/kg-d)
RfD	=	contaminant-specific chronic reference dose (mg/kg-d)

C-4.1 EXAMPLE CALCULATIONS

All example calculations are made using intake values calculated above for arsenic and uranium with the exception of the hazard quotient for the inhalation pathway. Mercury with an intake of 1.4E-07 mg/kg-d, is used for this example because arsenic does not have an inhalation RfD.

C-4.1.1 Soil Ingestion

Lifetime Incremental Cancer Risk - Arsenic

$$ICR = 1.9E\text{--}06 \text{ mg/kg-d} \times 1.7 \text{ } (mg/kg\text{--}d)^{-1} = 3E\text{--}06 \qquad \text{C-53}$$

Lifetime Incremental Cancer Risk - Uranium-238

$$ICR = 1.7E+03 \text{ pCi} \times 2.8E\text{-}11 \text{ } (pCi)^{-1} = 5E\text{-}08 \qquad \text{C-54}$$

<u>Hazard Quotient</u> - Arsenic

$$HQ = \frac{1.6E-05 \text{ mg/kg-d}}{3.0E-04 \text{ mg/kg-d}} = 0.053 \qquad\qquad \text{C-55}$$

C-4.1.2 Inhalation

C-4.1.2.1 <u>Inhalation of Fugitive Dust</u>

<u>Lifetime Incremental Cancer Risk</u> - Arsenic

$$ICR = 2.2E\text{-}09 \text{ mg/kg-d} \times 50 \ (\text{mg/kg-d})^{-1} = 1E\text{-}07^* \qquad \text{C-56}$$

*The SF is modified based on the assumption that 30% of inhaled arsenic is absorbed.

<u>Lifetime Incremental Cancer Risk</u> - Uranium-238

$$ICR = 14.3 \text{ pCi/m}^3 \times 5.2E\text{-}08 \ (\text{pCi})^{-1} = 7E\text{-}07 \qquad \text{C-57}$$

<u>Hazard Quotient</u> - Mercury

$$HQ = \frac{1.4E-07 \text{ mg/kg-d}}{8.6E-05 \text{ mg/kg-d}} = 0.002 \qquad\qquad \text{C-58}$$

C-4.1.3 External Exposure

<u>Lifetime Incremental Cancer Risk</u> - Uranium-238

$$ICR = 29.9 \text{ pCi-yr/g} \times 3.6E\text{-}08 \ (\text{pCi-yr/g})^{-1} = 1E\text{-}06 \qquad \text{C-59}$$

C-5.0 CALCULATION OF RISK-BASED CONCENTRATIONS
(RISK CHARACTERIZATION WHEN LFI DATA ARE NOT AVAILABLE)

As discussed in Section C.2.4.2 of the HSBRAM (DOE-RL 1993a), a comparison of estimated site concentrations in a medium is performed when LFI data are not available. The risk-based concentrations are calculated for soil concentrations that would be equivalent to exposures at an HQ of 1 for non-carcinogenic effects. An incremental lifetime cancer risk (ICR) of 1E-06 is used for evaluating contaminants with carcinogenic effects. The basic equation to calculate risk-based concentrations are the same equations used for risk-based screening (equations C1, C2 and C3) with the HQ and ICR replaced by unity and 1E-06, respectively. The following calculation example presents the ingestion, inhalation and external exposure pathways for the frequent-use scenario. The occasional-use scenario would utilize the same equations but the exposure parameters would be those indicated in Table C-2 for the occasional-use scenario.

C-5.0.1 Soil Ingestion

<u>Carcinogenic - Non-Radioactive</u>

$$ C = \frac{TR \times AT \times CF}{SF \times \left[\left(\frac{IR \times EF \times ED}{BW} \right)_{Child} + \left(\frac{IR \times EF \times ED}{BW} \right)_{Adult} \right]} $$

$$ C \ (mg/kg) = \frac{(1E-06)(365 \ d/yr \times 70 \ yr)(1E+06 \ mg/kg)}{SF \ (mg/kg-d)^{-1} \left[\left(\frac{(200 \ mg/d)(365 \ d/yr)(6 \ yr)}{16 \ kg} \right)_{Child} + \left(\frac{(100 \ mg/d)(365 \ d/yr)(24 \ yr)}{70 \ kg} \right)_{Adult} \right]} $$

$$ C \ (mg/kg) = \frac{6.4E-01 \ d}{SF \ (mg/kg-d)^{-1}} $$

C-60

<u>Carcinogenic - Radioactive</u>

$$C = \frac{TR \times CF}{SF \times \left[(IR \times EF \times ED)_{Child} + (IR \times EF \times ED)_{Adult}\right]}$$

$$C\ (pCi/g) = \frac{(1E{-}06)(1E{+}03\ mg/g)}{SF\ (pCi)^{-1}\left[(200\ mg/d)(365\ d/yr)(6\ yr)_{Child} + (100\ mg/d)(365\ d/yr)(24\ yr)_{Adult}\right]}$$

$$C\ (pCi/g) = \frac{7.6E{-}10\ (g)^{-1}}{SF\ (pCi)^{-1}} \qquad \textbf{C-61}$$

<u>Noncarcinogenic</u>

$$C = \frac{THQ \times RfD \times BW \times AT \times CF}{IR \times EF \times ED}$$

$$C\ (mg/kg) = \frac{(1)(RfD\ mg/kg{-}d)(16\ kg)(365\ d/yr \times 6\ yr)(1E{+}06\ mg/kg)}{(200\ mg/d)(365\ d/yr)(6\ yr)} \qquad \textbf{C-62}$$

$$C\ (mg/kg) = RfD\ (mg/kg{-}d) \times 8E{+}04\ d$$

C-5.0.2 Inhalation of Fugitive Dust

<u>Carcinogenic - Non-Radioactive</u>

$$C = \frac{TR \times BW \times AT \times PEF}{SF \times IR \times EF \times ED}$$

$$C\ (mg/kg) = \frac{(1E{-}06)(70\ kg)(365\ d/yr \times 70\ yr)(2E{+}07\ m^3/kg)}{SF\ (mg/kg{-}d)^{-1}(20\ m^3/d)(365\ d/yr)(30\ yr)} \qquad \textbf{C-63}$$

$$C\ (mg/kg) = \frac{1.6E{+}02\ d}{SF(mg/kg{-}d)^{-1}}$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

Carcinogenic - Radioactive

$$C = \frac{TR \times PEF \times CF}{SF \times IR \times EF \times ED}$$

$$C \ (pCi/g) = \frac{(1E-06)(2E+07 \ m^3/kg)(1E-03 \ kg/g)}{SF \ (pCi)^{-1}(20 \ m^3/d)(365 \ d/yr)(30 \ yr)} \qquad \textbf{C-64}$$

$$C \ (pCi/g) = \frac{9.1E-08 \ (g)^{-1}}{SF(pCi)^{-1}}$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

Noncarcinogenic

$$C = \frac{THQ \times RfD \times BW \times AT \times PEF}{IR \times EF \times ED}$$

$$C \ (mg/kg) = \frac{(1)(RfD \ mg/kg-d)(16 \ kg)(365 \ d/yr \times 6 \ yr)(2E+07 \ m^3/kg)}{(10 \ m^3/d)(365 \ d/yr)(6 \ yr)} \qquad \textbf{C-65}$$

$$C \ (mg/kg) = RfD \ (mg/kg-d) \times 3E+07 \ d$$

Note: PEF is a soil-to-air respirable factor (see Table C-1).

C-5.0.3 External Exposure

This pathway applies exclusively to radioactive contaminants, which are evaluated only for their carcinogenic potential.

$$C = \frac{TR}{SF \times IR \times EF \times ED \times RF}$$

$$C \ (pCi/g) = \frac{1E{-}06}{SF \ (pCi\text{-}yr/g)^{-1}(2.7E{-}03 \ yr/d)(365 \ d/yr)(30 \ yr)(0.8)} \qquad \text{C-66}$$

$$C \ (pCi/g) = \frac{4.2E{-}08 \ (yr)^{-1}}{SF(pCi\text{-}yr/g)^{-1}}$$

RF - Dose reduction factor (unitless).

C-5.1 EXAMPLE CALCULATIONS

For the ingestion and inhalation exposure to non-radioactive soil contaminants, arsenic and mercury are used for example calculations. Uranium-238 is used for the radioactive contaminants.

C-5.1.1 Soil Ingestion

<u>Carcinogenic - Non-Radioactive</u> - Arsenic

$$C = \frac{6.4E{-}01 \ d}{1.7(mg/kg\text{-}d)^{-1}} = 0.38 \ mg/kg \qquad \text{C-67}$$

<u>Carcinogenic - Radioactive</u> - Uranium-238

$$C = \frac{7.6E{-}10(g)^{-1}}{2.8E{-}11(pCi)^{-1}} = 27 \ pCi/g \qquad \text{C-68}$$

<u>Noncarcinogenic</u> - Arsenic

$$C = 3E{-}04 \ mg/kg\text{-}d \times 8E{+}04 \ d = 24 \ mg/kg \qquad \text{C-69}$$

C-5.1.2 Inhalation

<u>Carcinogenic - Non-Radioactive</u> - Arsenic

$$C = \frac{1.6E+02 \text{ d}}{50 \text{ (mg/kg-d)}^{-1})(0.3)^{*}} = 11 \text{ mg/kg} \qquad \text{C-70}$$

* The SF is modified based on the assumption that 30% of inhaled arsenic is absorbed.

<u>Carcinogenic - Radioactive</u> - Uranium-238

$$C = \frac{9.1E-08(g)^{-1}}{5.2E-08(pCi)^{-1}} = 1.8 \text{ pCi/g} \qquad \text{C-71}$$

<u>Noncarcinogenic</u> - Mercury

$$C = 8.6E-05 \text{ mg/kg-d} \times 3E+07 \text{ d} = 2,600 \text{ mg/kg} \qquad \text{C-72}$$

C-5.1.3 External Exposure

<u>Carcinogenic - Radioactive</u> - Uranium-238

$$3C = \frac{4.2E-08(yr)^{-1}}{3.6E-08(pCi-yr/g)^{-1}} = 1.17 \text{ pCi/g} \qquad \text{C-73}$$

Table C-2. Summary of Recreational and Residential Scenarios Exposure Factors.

Exposure Factors	HSBRAM Reasonable Maximum Exposure[a]	
	Recreational[b]	Residential[c]

Intake Rate
  Soil Ingestion
  Inhalation
    Noncarcinogens
    Carcinogens
	200(C) 100(A) mg/d
	
	10 m^3/d
	20 m^3/d
		200(C) 100(A) mg/d
		
		10 m^3/d
		20 m^3/d

Exposure Frequency
  Soil Ingestion
  Inhalation
	7 d/yr
	7 d/yr
		365 d/y
		365 d/y

Exposure Duration
  Soil Ingestion
  Inhalation
    Noncarcinogens
    Carcinogens
	6(C) 24(A) yr
	
	6 yr
	30 yr
		6(C) 24(A) yr
		
		6 yr
		30 yr

Body Weight	16(C) 70(A) kg	16(C) 70(A) kg

Averaging Time
  Noncarcinogens
  Carcinogens
	6 yr x 365 d/yr
	70 yr x 365 d/yr
		6 yr x 365 d/yr
		70 yr x 365 d/yr

Dose Reduction Factor (external exposure)	0.8 (unitless)	0.8 (unitless)
(C) Child (A) Adult [a]DOE-RL 1993a [b]Recreational exposure parameters used to evaluate occasional-use scenarios [c]Residential exposure parameters used to evaluate frequent-use scenarios		

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX D

ECOLOGICAL INFORMATION AND CALCULATIONS

THIS PAGE INTENTIONALLY LEFT BLANK

Ecological Characterization of the 100 Area

Plants

The plant communities within the 100-H Area are broadly characterized as riparian immediately adjacent to the Columbia River and sagebrush-steppe in areas away from the shoreline. Sackschewsky and Landeen (1992) reported that the plant community within the 100-HR-1 operable unit fence consists almost entirely of an alien weed community dominated by cheatgrass (Bromus tectorum), tumblemustard (Sisymbrium altissimum), and Russian thistle (Salsola kali), with scattered gray rabbitbrush (Chrysothamnus nauseosus). The riparian community contains a number of trees, including white mulberries (Morus alba), Siberian elm (Ulmus pumila), and Rocky Mountain juniper (Juniperus scopulorum). The surrounding sagebrush-steppe habitat is dominated by big sagebrush (Artemisia tridentata), with an understory of cheatgrass and Sandberg's bluegrass (Poa sandbergii). Sackschewsky and Landeen (1992) observed no species listed as threatened, endangered, candidate, or sensitive by the federal or Washington State governments. The principle plant of the 100-HR-1 operable unit waste sites were Russian thistle, cheatgrass and rabbitbrush (Sackschewsky and Landeen 1992).

Rooting depths of plants are important in evaluating their exposure to buried contaminants. Big sagebrush on the 200 Area plateau has been found to have an average maximum rooting depth of 200 cm (78.8 in) (±12 cm [4.7 in] std. error); other shrubs in this habitat type ranged from 153 to 195 cm (60.2 to 76.8 in) (Klepper et al. 1985). Large perennial grasses of the big sagebrush/Sandberg's bluegrass habitat have been found with maximum rooting depths of 120 to 140 cm (47.2 to 55.1 in) (Klepper et al. 1985). Sandberg's bluegrass roots extend to 35 cm (13.7 in), while cheatgrass roots may extend to 45 cm (17.7 in) (Link et al. 1990). Other plants of disturbed sites, particularly Russian thistle and ragweed (Ambrosia acanthicarpa), have maximum rooting depths of 172 cm (67.7 in) (±11 cm [4.3 in]) and 162 cm (63.8 in) (±8 cm [3.1 in]), respectively (Klepper et al. 1985).

Birds

Bird species observed in the 100 Area are listed in Sackschewsky and Landeen (1992). A general review of birds observed on the Hanford Site along with their general habitat associations was prepared by Fitzner and Gray (1991). Sixteen birds that occur on the Hanford Site are listed as endangered or threatened by the State of Washington or the federal government, or are candidates for such listing (Table D-1). All have been observed in the vicinity of the Columbia River near the 100 Areas.

Bald eagles do not currently nest on the Hanford Site. The wintering population of bald eagles has been increasing in recent years (Fitzner and Hanson 1979). Bald eagles are present from November through March. Overwintering eagles on the Hanford Reach of the Columbia River primarily forage on Chinook salmon (Oncorhynchus tchawytscha) and mallard ducks (Anas platyrhynchos) (41 and 39% of dietary biomass respectively) (Fitzner and Hanson 1979). Other foods eaten include other waterfowl and fish species associated with the river ecosystem (Fitzner and Hanson 1979).

The peregrine falcon is an infrequent visitor to the Hanford Site. This species is not resident, and peregrine falcons do not nest on the site. Peregrine falcons are occasionally noted during the winter months during migration and may winter in the

area, particularly near the Yakima Delta. Peregrine falcons elsewhere are known to feed primarily on birds, although their food habits on the Hanford Site are not known.

Because of their extreme rarity on the site, and the very short duration of their residence here (days), Hanford Site contaminants are not considered to be a significant risk to their existence.

Loggerhead shrikes are year-round residents on the Hanford Site, although they occur at relatively low densities (Fitzner et al. 1981). They nest from March through August in undisturbed portions of the big sagebrush/Sandberg's bluegrass community, where they average 3.5 pairs/km^2 (3.5 pairs/0.39 mi^2) in the 200 Area plateau (Poole 1992). These medium-sized passerines feed on insects, small mammals, and birds (Fitzner and Rickard 1975).

Approximately 50 pairs of ferruginous hawks nested in the state of Washington as of 1991 (Fitzner et al. 1992). Ten active ferruginous hawk nests were found on the Hanford Site as of 1991, with eight located in high-tension electric transmission towers and two in trees (Fitzner et al. 1992). These hawks feed primarily on small to medium-sized mammals such as rabbits and ground squirrels (Howard and Wolfe 1976, Fitzner et al. 1981).

Approximately 15-20 pairs of Swainson's hawks nest on the Hanford Site (Fitzner et al. 1981). The birds nest in trees on the Hanford Site from April to September. Swainson's hawks feed primarily on snakes, medium-sized mammals, and insects, with yellow-bellied racers being the most important prey (Fitzner 1980). The nearest nesting location to the 100-H Area is located within 3.5 km (2.2 mi) distance.

In 1977, approximately 60 pairs of long-billed curlews were estimated to have been nesting in the 600 Area of the Hanford Site (Allen 1980). Curlews nest from April through June in relatively flat areas dominated by cheatgrass. They feed primarily on beetles and subterranean insect larvae (Allen 1980). No systematic surveys of the site have been conducted since Allen's study (Fitzner et al. 1992).

Burrowing owls are widely distributed on the Hanford Site. The nesting population during the mid-1970s was estimated at 20-26 pairs (Fitzner et al. 1981). Most nest sites are found in abandoned badger and coyote burrows. No systematic survey of the Hanford Site has been conducted to determine the nesting locations of these birds (Rickard and Poole 1989). These small owls are primarily insect and small mammal predators. Insects represent the majority of prey captures, but Great Basin pocket mice (*Perognathus parvus*) form the major part of their diet in terms of biomass (Fitzner et al. 1981).

Sage sparrows are a common summer resident of the 200 Area plateau (Fitzner and Rickard 1975). These small passerines are restricted in their distribution almost entirely to sagebrush stands (Schuler et al. 1988). Sage sparrow abundance on the 200 Area plateau has been shown to be related to sagebrush density (Schuler et al. 1988), although abundance may vary widely between years due to natural environmental variation (Rotenberry 1980). Sage sparrows are the second most abundant bird in the undisturbed areas of the 200 Area plateau, reaching densities of 7.5 birds/km^2 (7.5 birds/0.39 mi^2) (Schuler et al. 1988). They forage primarily on phytophagous (plant-eating) beetles and other arthropods, with seeds composing less than 5% of their diet (Rotenberry 1980).

The sage thrasher is confined to areas of big sagebrush cover, where it consumes primarily insects and spiders on the ground rather than in the canopy (Terres 1980). Sage thrashers are resident on Hanford from spring into the fall (Fitzner and Gray 1991), although at very low densities (Schuler et al. 1988).

The most abundant bird found in the shrub-steppe habitat is the western meadowlark (Brandt and Rickard 1992). Western meadowlarks are present on the Hanford Site throughout the year (Fitzner and Rickard 1975). These passerines nest on the ground from April through July (Brandt and Rickard 1992). Their diet is composed almost entirely of phytophagous insects (Rotenberry 1980). Meadowlark abundance in sagebrush habitat on the Hanford Site was estimated to be approximately 11 birds/km (6.8 birds/mi) (Schuler et al. 1988).

Red-tailed hawks are the most common hawks nesting on the Hanford Site. At least 20 nesting pairs occupy the site. On the Hanford Site, most nesting occurs in utility towers, on Gable Butte, and in larger trees (Fitzner 1980). Red-tailed hawks on the Hanford Site primarily feed on medium-sized mammals such as black-tailed jackrabbits and Townsend's ground squirrels, and on snakes (Fitzner 1980). Red-tails nest within 2 km (1.24 mi) of the 100-H Area.

Great Basin Canada geese nest on the islands in the Columbia River and forage on the grasses on the Hanford Site (Gano and Rickard 1982; Rickard et al. 1990). The use of the 100-H Area by Canada geese has not been examined.

Mammals

A survey of the mammals of the 100 Areas was reported by Sackschewsky and Landeen (1992). Species known or likely to be present in the vicinity of the 100-HR-1 operable unit waste sites are listed in Table D-2. The mammalian species of concern with regard to endangered species protection in the 100 Areas is the Pacific western big-eared bat, a candidate for state and federal protection. While this bat has never been found on the Hanford Site, surveys have not been done to establish their presence. However, suitable habitat exists.

The herbivorous/granivorous mammalian component on the 100 Area is dominated by small mammals, particularly Great Basin pocket mice and deer mice. Other abundant herbivores include Townsend's ground squirrels and black-tailed jack rabbits. Near buildings, Nuttal's cottontails are more abundant than are jack rabbits. The large herbivore in 100 Area is the mule deer. The predominant carnivorous mammals are coyotes and badgers.

The most abundant small mammal on the 100 Area is the Great Basin pocket mouse (O'Farrell 1975). Although primarily a granivore, the pocket mouse also consumes insects early in the year before seed production (Kritzman 1974). Pocket mice constitute the principal prey items in the diets of burrowing owls, great horned owls, long-eared owls, and barn owls foraging on the Hanford Site (Fitzner 1980). Densities may range between 20 and 75 mice/ha (20 and 75 mice/2.47 acres) in April depending on the habitat (Gano and Rickard 1982). Densities in cheatgrass habitat have been estimated at 30/ha (30/2.47 acres) (Hedlund et al. 1975).

The second most abundant mammal on the Hanford Site is the deer mouse. Deer mice are omnivorous, concentrating on green vegetation, especially tansy mustard and

cheatgrass (Hedlund and Rogers 1976). Although nocturnal, they are found as occasional prey items in the diets of Swainson's hawks and red-tailed hawks nesting on the Hanford Site. More frequently, they are consumed by great horned owls, long-eared owls, burrowing owls, and barn owls (Fitzner 1980).

Townsend's ground squirrels are also present in the 100 Area: Hedlund and Rickard (1981) identified Townsend's ground squirrels as the second most prevalent small mammal, with peak catches between one half and one fifth that for the Great Basin pocket mouse. Foraging preferences based on analyses of fecal samples identified Sandberg's bluegrass and tumble mustard as preferred food items (Rogers and Gano 1980). Townsend's ground squirrels are the principal food item for red-tailed hawks and the second most important item in the diet of post-fledgling Swainson's hawks fledged on the Hanford Site
(Fitzner 1980).

Black-tailed Jack rabbits are found in nearly all habitats in the shrub-steppe region and are the most common lagomorph on the Hanford Site (Rickard et al. 1974). Black-tailed Jack rabbits in the big sagebrush/Sandberg's bluegrass communities feed most heavily on needle-and-thread grass, yarrow, turpentine cymopterus, and tumble mustard (Uresk et al. 1975). Black-tailed hares are the principal prey of golden eagles wintering on the Hanford Site (Rickard et al. 1974) and are important constituents in the diets of great horned owls, long-eared owls, barn owls, ferruginous hawks, Swainson's hawks, and red-tailed hawks (Fitzner 1980).

Mule deer are common and widespread on the Hanford Site. Mule deer are usually dispersed throughout favorable habitats of the Hanford Site in small groups or singly. Mule deer of the Hanford Site are mainly forb and shrub consumers (Uresk and Uresk 1980). Natural mortality of mule deer fawns on the Hanford Site is relatively high, mostly as a result of coyote predation (Steigers and Flinders 1980). Mule deer home ranges on the Site vary about a mean of approximately 40 km^2 (15.6 mi^2) (Eberhardt et al. 1982), with densities near the Columbia River of approximately 1 deer/60 ha (Steigers and Flinders 1980).

Coyotes are the most abundant carnivores on the Hanford Site. They have not been studied to any extent on the Hanford Site except on the Arid Lands Ecology Reserve (ALE). Their diet is diverse, reflecting the availability of prey. Where the Great Basin pocket mouse is most abundant in the habitat, they have been found to be most abundant in the coyote diet (Stoel 1976). Other prey include leporids, voles, pocket gophers, ground squirrels, mule deer fawns, birds, reptiles, beetles, and grasshoppers (Stoel 1976; Steigers and Flinders 1980). Coyote density on ALE has been estimated at 1 coyotes/2.5 km^2 (1 coyote/0.97 mi^2) (Crabtree 1989); Steigers and Flinders (1980) estimated coyote density near the Columbia River to be 1 coyote/4 km^2 (1 coyote/1.6 mi^2).

Reptiles

Reptiles that could occur near or in the 100-H Area include the western yellow-bellied racer (*Coluber constrictor*), the Great Basin gopher snake (*Pituophis melanoleucus*), the northern Pacific rattlesnake (*Crotalus viridus*), the desert nightsnake (*Hypsiglena torguata*), the striped whipsnake (*Masticophis taeniatus*), the sagebrush lizard (*Sceloporus graciosus*), the side-blotched lizard (*Uta stansburiana*), and the pygmy short-horned lizard (*Phrynosoma douglassi*) (Rogers and Rickard 1977). The most common reptiles found in the big sagebrush/Sandberg's bluegrass habitat are side-blotched lizards and yellow-

bellied racers (Marr et al. 1988). Side-blotched lizards were found in approximate densities of 15 lizards/ha (15 lizards/2.47 acres) in the 100 Area sites, in the 1970s (Rogers and Rickard 1977). The only reptile with Federal or state classification is the striped whipsnake, a state candidate species.

Insects

Insects and spiders are an important component of the plant communities of the 100-H Area in terms of biomass and ecological role. Invertebrate densities in sagebrush/bunchgrass habitat on ALE ranged from 450 to nearly 2000 individuals/m^2 (10.7 ft^2), with a biomass of up to 0.5 g/m^2 (Rogers 1977). The predominant taxa include ground-dwelling darkling beetles (family Tenebrionidae), and shrub-dwelling bugs (order Homoptera), grasshoppers (order Orthoptera), true bugs (order Hemiptera), and spiders (order Araneida) (Rogers 1979, ERDA 1975, Weiss and Mitchell 1992). The two latter references contain tables of insect species found on the entire Hanford Site. Harvester ants, a potentially significant component in the exposure of buried contaminants (Fitzner et al. 1979), were observed on the waste sites within the 100 Area (Sackschewsky and Landeen 1992).

Dose Calculations for Terrestrial Receptors

This section describes the methods used to estimate intake of constituents of concern in surface soils by Great Basin pocket mouse and loggerhead shrike. Shown are typical receptor weights, food ingestion rates, and effective radius (radius of the receptor used in the radiological dose calculations). Dose from radionuclides was calculated based upon the computer code developed by Baker and Soldat (1992). The code was verified subsequent to publication of the document.

Radionuclide concentrations in primary organisms can be calculated directly from soil concentrations and transfer factors. The primary organism is a plant. Radionuclide concentrations for secondary organisms can be calculated from their diet of primary organisms. The transfer coefficients from soil to plants are given in Table D-3. For insects, an arbitrary transfer coefficient of 1:1 was used. The accuracy of this value is not known because no information relating transfer of study constituents from soil to insects was found. This estimate has a high uncertainty.

The internal total-body dose rate to an organism for N radionuclides is given as

$$R_c = \sum_{i=1}^{N} b_{i,c} \, E_{i,c} \qquad (1)$$

where R_c = dose rate to total body of organism c (rad d^{-1}),

$E_{i,c}$ = effective absorbed energy rate for nuclide i per unit activity in organism c (kg rad Ci^{-1} d^{-1}).

$$E_{i,c} = \epsilon_{i,c} MeV \; dis^{-1} \; x \; 3.70E10 \; dis \; s^{-1} \; Ci^{-1}$$

$$86,400 \; s \; d^{-1} \; x \; 1.602E\text{-}11 \; kg \; rad \; MeV^{-1} = 5.12E4 \; \epsilon_{i,c}$$

where ϵ is the effective absorbed energy for nuclide i in organism c.

$b_{i,c}$ = specific body burden of nuclide i in organism c (Ci kg^{-1}).

For a primary organism,

$$b_{i,c} = C_{i,c} B_{i,c} \qquad (2)$$

where $C_{i,c}$ is concentration of nuclide i in soil to which organism c is exposed (Ci m^{-3}), and $B_{i,c}$ is bioaccumulation factor for nuclide i and organism c (m^3 kg^{-1}).

Combining equations (1) and (2) yields the dose rate in rad d^{-1} to the primary organism

$$R_c = \sum_{i=1}^{N} C_{i,c} B_{i,c} E_{i,c} \qquad (3)$$

For the secondary organism, such as herbivores and carnivores we can write an expression for a single radionuclide equating the change in body burden to the uptake and removal of the radionuclide

$$\frac{db^s}{dt} = \frac{P}{M} - \lambda b^s \qquad (4)$$

where b^s = specific body burden of the secondary organism (Ci kg^{-1})

P = rate of uptake of radionuclide by body of organism (Ci d^{-1})

λ = $(\lambda_b + \lambda_r)$ effective decay constant in secondary organism, (d^{-1}), where λ_b = ln(2)/T$_b$ is the biological removal rate constant for the nuclide in the secondary organism and λ_r = ln(2)/T$_r$ is the radiological decay constant for the nuclide

M = mass of secondary organism (kg).

The secondary organism uptake rate is given by

$$P = b \, U_i \, f_1 \qquad (5)$$

where b = body burden of primary organism (Ci kg^{-1})

U = intake rate of primary organism by predator (kg d^{-1})

f_1 = fraction of radionuclide initially retained in total body of secondary organism (unitless).

Solving equation (4) with b^s = 0 when t = 0:

$$b^s = \frac{P}{M} \frac{(1-e^{-\lambda T_c})}{\lambda} \tag{6}$$

where T_e is the period of exposure (d).

Then, for a secondary organism c, the dose rate in terms of the body burden, b_i, of the primary organism or prey for N radionuclides is

$$R_c = \sum_{i=1}^{N} \frac{B_i U_c f_{1,i}}{M_c} \frac{(1-e^{-\lambda_{i,c} T_c})}{\lambda_{i,c}} E_{i,c} \tag{7}$$

where U_c = intake rate of primary organism by secondary organism c (kg d^{-1})

$\lambda_{i,c}$ = effective decay constant of nuclide i in secondary organism c (d^{-1})

m_c = mass of secondary organism c (kg).

In the absence of specific data, the removal constants, $\lambda_{i,c}$, and uptake fractions, $f_{1,i}$, are taken to be that of Standard Man as derived from Publication 2 of the International Commission on Radiological Protection (ICRP 1959). The values of effective energy, $\epsilon_{i,c}$, were determined knowing the effective radius of the organism. The exposure time, T_e, is usually assumed to be 1 year for regulatory purposes, and the concentration is averaged over 1 year. The external dose to wildlife from radionuclides was not calculated because it has been shown to be a minor contributor to dose (Poston and Soldat 1992).

Intake of contaminants by the pocket mouse was estimated using intake parameters from published literature or derived from EPA formulas (EPA 1988). Intake of contaminants in vegetation was estimated using Equation 6, of EPA's Human Health Evaluation Manual (EPA 1989) in which:

$$Iv = (Cv)(Qv)(FI)(EF)(ED)/(BW)(AT) \tag{8}$$

where

Iv   = intake of contaminant in vegetation (mg/kg/day)
Cv   = concentration in vegetation (mg/kg)
Qv = ingestion rate (kg/day)
FI   = fraction ingested from contaminated source = 1
EF   = exposure frequency (days/year)
ED   = exposure duration (years)
BW   = body weight (kg)
AT   = average time, (ED)(365 days/year)

For the organisms that spend their entire life in a waste site, average time, exposure duration, and exposure frequency can be eliminated from all intake equations. The fraction ingested from a contaminated source was based on the animal's home range and the amount of food expected to be consumed from contaminated areas. Feeding rates are typically reported on a wet-weight basis, while contaminant concentrations in soil and biota are reported on a dry-weight basis.

The concentration factors from soil to the generic plant was obtained from available literature. The maximum reported transfer coefficients from soil to plants were used in all dose calculations. These values were used to model plants as a food source in successive trophic levels.

Pocket mice were assumed to spend their entire life in a waste site; hence, average time, exposure duration, and exposure frequency is not important. Transfer of contaminants from ingestion of prey species were either estimated from available literature·or from plant to beef transfer coefficients: If site-specific data were not available for transfer from plants to mouse, plant to beef values were used.

REFERENCES

Allen, J. N., 1980, *The Ecology and Behavior of the Long-billed Curlew in Southeastern Washington*, The Wildlife Society, Bethesda, Maryland.

Baker, D. A., and J. K. Soldat, 1992, *Methods for Estimating Doses to Organisms from Radioactive Materials Released into .the Aquatic Environment*, PNL-8150, Pacific Northwest Laboratory, Richland, Washington.

Brandt, C. A., and W. H. Rickard, 1992, "Effects of Survey Frequency on Bird Sensitivity Estimates in the Shrub-steppe Environment", *Northwest Science* Vol. 66, pp. 172-182.

Coughtrey, P.J., D. Jackson, C.H. Jones, P. Kane, and M. C. Thorne, 1985, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems*, A. A. Balkema, Rotterdam, Netherlands.

Crabtree, R. L., 1989, *Sociodemography of an Unexploited Coyote Population*, PhD Dissertation, University of Idaho, Moscow, Idaho.

DOE, 1992, *Site-Wide Characterization Report, Fernald Environmental Management Project*, FEMP-SWCR-3, U.S. Department of Energy, Fernald Field Office, Fernald, Ohio.

Eberhardt, L. E., E. E. Hanson, and L. L. Cadwell, 1982, *Analysis of Radionuclide Concentrations and Movement Patterns of Hanford Site Mule Deer*, PNL-4420, Pacific Northwest Laboratory, Richland, Washington.

EPA, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA; Interim Final*, EPA/540/G-89/004, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1989, *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Part A, Interim Final*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C.

ERDA, 1975, *Final Environmental Statement Waste Management Operations, ERDA-1538, Vol. 1*, Energy Research and Development Administration, Richland, Washington.

Fitzner, R. E., 1980, *Behavioral Ecology of the Swainson's Hawk (Buteo swainsoni) in Washington*, PNL-2754, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E., K. A. Gano, W. H. Rickard, and L. E. Rogers, 1979, *Characterization of the Hanford 300 Area Burial Grounds*, PNL-2774, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E., and R. H. Gray, 1991, "The Status, Distribution and Ecology of Wildlife on the U.S. DOE Hanford Site: A Historical Overview of Research Activities," *Environmental Monitoring and Assessment*, Vol. 18, pp. 173-202.

Fitzner, R. E., and W. C. Hanson, 1979, "A Congregation of Wintering Bald Eagles", *Condor*, Vol. 81, pp. 311-313.

Fitzner, R. E., and W. H. Rickard, 1975, *Avifauna of Waste Ponds, ERDA Hanford Reservation, Benton County, Washington*, BNWL-1885, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E., W. H. Rickard, L. L. Cadwell, and L. E. Rogers, 1981, *Raptors of the Hanford Site and Nearby Areas of Southcentral Washington*, PNL-3212, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E., S. G. Weiss, and J. A. Stegen, 1992, *Biological Assessment for Threatened and Endangered Wildlife Species Related to CERCLA Characterization Activities*, WHC-EP-0513, Westinghouse Hanford Company, Richland, Washington.

Gano, K. A. and W. H. Rickard, 1982, "Small Mammals of a Bitterbrush-Cheatgrass Community", *Northwest Science*, Vol. 56, pp. 1-7.

Hedlund, J. D., D. T. McCullugh, and W. H. Rickard, 1975, "Mouse Populations on Knob and Kettle Topography in South-central Washington", *Northwest Science*, Vol 49, pp. 253-260.

Hedlund, J.D., and Rickard W.H., 1981, Wildfire and the Short-term Response of Small Mammals Inhabiting a Sagebrush-bunchgrass Community, *The Murrelet*. 62:10-14.

Hedlund, J. D., and L. E. Rogers, 1976, *Characterization of Small Mammal Populations Inhabiting the B-C Crib Environs*, BNWL-2181, Pacific Northwest Laboratory, Richland, Washington.

Howard, R. P., and M. L. Wolfe, 1976, "Range Improvement Practices and Ferruginous Hawks", *Journal of Range Management*, Vol. 29, pp. 33-37

ICRP, 1959, *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 2, Pergamon Press, Oxford, England.

Klepper, E. L., K. A. Gano, and L. L. Cadwell, 1985, *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site*, PNL-5247, Pacific Northwest Laboratory, Richland, Washington.

Kritzman, E. B., 1974, "Ecological Relationships of *Peromyscus maniculatus* and *Perognathus parvus* in Eastern Washington", *Ecology*, Vol. 77, pp. 172-188.

Marr, N. V., C. A. Brandt, R. E. Fitzner, and L. D. Poole, 1988, *Habitat Associations of Vertebrate Prey within the Controlled Area Study Zone*, PNL-6495, Pacific Northwest Laboratory, Richland, Washington.

Miller, M. L., et al., 1977, *Radiochemical Analysis of Soil and Vegetation Samples Taken from the Hanford Environs. 1971-1976*, BNWL-2249, Pacific Northwest Laboratory, Richland, Washington.

O'Farrell, T. P., 1975, "Small Mammals, their Parasites and Pathologic Lesions on the Arid Lands Ecology Reserve, Benton County, Washington", *American Midland Naturalist*, Vol. 93, pp. 377-387.

Poole, L. D., 1992, *Reproductive Success and Nesting Habitat of Loggerhead Shrikes in Shrubsteppe Communities*, MS Thesis, Oregon State University, Corvallis, Oregon.

Poston, T. M., and J. K. Soldat, 1992, *Scoping Assessment of Radiological Doses to Aquatic Organisms and Wildlife - N Springs*, PNL-8360, Pacific Northwest Laboratory, Richland, Washington.

Rickard, W. H., J. D. Hedlund, and R. G. Schreckhise, 1974, *Mammals of the Hanford Reservation in Relation to Management of Radioactive Waste*, BNWL-1877, Pacific Northwest Laboratory, Richland, Washington.

Rickard, W. H., and L. D. Poole, 1989, "Terrestrial Wildlife of the Hanford Site, Washington, U.S.A., Past and Future", *Northwest Science*, Vol. 63, pp. 183-193.

Rogers, L. E., 1977, "Analysis of Invertebrate Populations Inhabiting the Shrub-steppe Region of Southcentral Washington, "*National Environmental Research Park Symposium: Natural Resource Inventory, Characterization, and Analysis*, ORNL-5304, Kitchings, J.T., and N.E. Tarr, editors, Oak Ridge National Laboratory, Oak Ridge, Tennessee, pp. 83-93.

Rogers, L. E., and K. A. Gano, 1980, "Townsend Ground Squirrel Diets in the Shrub-steppe of Southcentral Washington", *Journal of Range Management*, Vol. 33, pp. 463-465.

Rogers, L. E., and W. H. Rickard, 1977, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*, PNL-2253, Pacific Northwest Laboratory, Richland, Washington.

Rotenberry, J. T., 1980, "Dietary Relationships Among Shrubsteppe Passerine Birds: Competition or Opportunism in a Variable Environment?", *Ecological Monographs*, Vol. 50, pp. 93-110.

Routson, R. C., and D. A. Cataldo, 1978, A Growth Chamber Study of the Effect of Soil Concentration and Plant Age on the Uptake of Sr and Cs by Tumbleweed, *Communications in Soil Science and Plant Analysis*, Vol. 9, pp. 215-230.

Sackschewsky, M. R., D. S. Landeen, G. I. Baird, W. H. Rickard, and J. L. Downs, 1992, *Vascular Plants of the Hanford Site*, WHC-EP-0554, Westinghouse Hanford Company, Richland, Washington.

Schuler, C. A., W. H. Rickard, and G. A. Sargeant, 1988, *Bird Associations with Shrubsteppe Plant Communities at the Proposed Reference Repository Location in Southeastern Washington*, PNL-6493, Pacific Northwest Laboratory, Richland, Washington.

Steigers, W. D., Jr., and J. T. Flinders, 1980, "Mortality and Movements of Mule Deer Fawns in Washington", *Journal of Wildlife Management*, Vol. 44, pp. 381-388.

Stoel, P. F., 1976, *Some Coyote Food Habit Patterns in the Shrub-Steppe of South-Central Washington*, M.S. Thesis, Portland State University, Portland, Oregon.

Terres, J. K., 1980, *The Audubon Society Encyclopedia of North American Birds*, Alfred A. Knopf, New York, New York.

Uresk, D. W., and V. A. Uresk, 1980, *Diets and Habitat Analyses of Mule Deer on the 200 Areas of the Hanford Site in Southcentral Washington*, PNL-2461, Pacific Northwest Laboratory, Richland, Washington.

Uresk, D. W., J. F. Cline, and W. H. Rickard, 1975, *Diets of Black-Tailed Hares on the Hanford Reservation*, BNWL-1931, Pacific Northwest Laboratory, Richland, Washington.

Weiss, S.G. and R.M. Mitchell, 1992, *A Synthesis of Ecological Data from the 100-Areas of the Hanford Site*, WHC-ET-0601, Westinghouse Hanford Company, Richland, Washington.

Whicker, F. W., and V. Schultz, 1982, *Radioecology: Nuclear Energy and the Environment, Vol. II*, CRC Press, Inc., Boca Raton, Florida.

Table D-1. Threatened, Endangered, and Candidate Birds of the Hanford Site
That May Occur in the Vicinity of the 100-H Area.

Common Name	Latin Name	Federal Status	State Status
bald eagle[a]	*Haliaeetus leucocephalus*	threatened	threatened
peregrine falcon[b]	*Falco peregrinus*	endangered	endangered
American white pelican[a]	*Pelecanus erythrorhynchos*	-	endangered
sandhill crane[a]	*Grus canadensis*	-	endangered
ferruginous hawk[a]	*Buteo regalis*	candidate	threatened
loggerhead shrike[a]	*Lanius ludovicianus*	candidate	candidate
sage grouse[b,c]	*Centrocercus urophasianus*	candidate	candidate
common loon[a]	*Gavia immer*	-	candidate
northern goshawk[c]	*Accipiter gentilis*	-	candidate
Swainson's hawk[a]	*Buteo swainsoni*	candidate-3	candidate
golden eagle[a]	*Aquila chrysaetos*	-	candidate
flammulated owl[c]	*Otus flammeolus*	-	candidate
burrowing owl[c]	*Athene cunicularia*	-	candidate
sage thrasher[c]	*Oreoscoptes montanus*	-	candidate
sage sparrow[a]	*Amphispiza belli*	-	candidate
long-billed curlew[a]	*Numenius americanus*	candidate-3	-

[a] Observed during 100 Area surveys (Sackschewsky and Landeen 1992).
[b] Accidental occurrence, not likely to be found on the area.
[c] 100 Area contains suitable habitat for this species.

Table D-2. Mammals of the Hanford Site Associated with the Riparian
Zone of the Columbia River. (Sheet 1 of 2).

Family	Common Name	Latin Name	Abundance	Habitat Association
Soricidae	vagrant shrew	*Sorex vagrans*	uncommon	riparian
Vespertilionidae	pallid bat	*Antrozous pallidus*	common - summer	buildings
	little brown myotis	*Myotis lucifugus*	common - summer	buildings
	Yuma myotis	*Myotis yumanensis*	common - summer	buildings
	western big-eared bat	*Plecotis townsendii*	unknown	buildings
Leporidae	black-tailed jackrabbit[a]	*Lepus californicus*	common	shrublands/grasslands
	Nuttall's cottontail[a]	*Sylvilagus nuttallii*	common	buildings
Sciuridae	Townsend ground squirrel	*Spermophilus townsendii*	common	shrublands/grasslands
Geomyidae	northern pocket gopher[a]	[a]*Thomomys talpoides*	common	shrublands/grasslands
Heteromyidae	Great Basin pocket mouse[a]	*Perognathus parvus*	common	shrublands/grasslands
Castoridae	beaver[a]	*Castor canadensis*	common	river/riparian
Cricetidae	western harvest mouse	*Reithrodontomys megalotis*	rare	shrublands/riparian
	deer mouse	*Peromyscus maniculatus*	common	entire site
	northern grasshopper mouse	*Onychomys leucogaster*	rare	riparian
	bushy-tailed wood rat[a]	*Neotoma cinerea*	common	entire site
	montane vole	*Microtus montanus*	rare	riparian
	sagebrush vole	*Lagurus curtatus*	rare	shrublands
	muskrat[a]	*Ondatra zibethica*	rare	river/riparian
Muridae	Norway rat	*Rattus norvegicus*	common	buildings
	house mouse	*Mus musculus*	common	buildings/riparian
Erethizontidae	porcupine[a]	*Erithizon dorsatum*	uncommon	entire site
Canidae	coyote[a]	*Canis latrans*	uncommon	entire site
Procyonidae	racoon	*Procyon lotor*	uncommon	riparian

Table D-2. Mammals of the Hanford Site Associated with the Riparian
Zone of the Columbia River. (Sheet 2 of 2).

Family	Common Name	Latin Name	Abundance	Habitat Association
Mustelidae	mink	*Mustela vison*	rare	river/riparian
	long-tailed weasel	*Mustela frenata*	uncommon	riparian
	short-tailed weasel	*Mustela erminea*	rare	riparian
	otter	*Lutra canadensis*	rare	river/riparian
	badger[a]	*Taxidea tasus*	uncommon	entire site
	striped skunk	*Mephitis mephitis*	uncommon	riparian
Felidae	bobcat	*Lynx rufus*	rare	entire site
Cervidae	mule deer[a]	*Odocoileus hemionus*	common	entire site
	white-tailed deer	*Odocoileus virginianus*	rare	riparian
[a]Mammals observed by Sackschewsky and Landeen (1992).				

Table D-3. General Soil-to-Plant Transfer Coefficients Used for Contaminants of Potential Concern.

Contaminant	Plant/Soil Transfer Coefficient	Reference
Americium-241	1.0E-02	Coughtrey et al. 1985
Carbon-14	5.5	Whicker and Schultz 1982
Cesium-134	2.5E-01	Coughtrey et al. 1985
Cesium-137	0.6	Miller et al. 1977
Cobalt-60	0.5	Coughtrey et al. 1985
Europium-152	0.001	Coughtrey et al. 1985
Europium-154	0.001	Coughtrey et al. 1985
Europium-155	0.001	Coughtrey et al. 1985
Nickel-63	0.1	Coughtrey et al. 1985
Plutonium-238	7.0E-02	Coughtrey et al. 1985
Plutonium-239	7.0E-02	Coughtrey et al. 1985
Radium-226	0.1	Coughtrey et al. 1983 and 1985
Strontium-90	19	Rouston and Cataldo 1978
Thorium-228	1.0E-04	Whicker and Schultz 1982
Tritium	4.8	Whicker and Schultz 1982
Uranium-234	1	Whicker and Schultz 1982
Uranium-235	1	Whicker and Schultz 1982
Uranium-238	1	Whicker and Schultz 1982
Antimony	0.1	Coughtrey et al. 1983 and 1985
Barium	0.15	DOE 1992
Benzo(a)pyrene	0.013	DOE 1992
Chromium	0.0075	DOE 1992
Chrysene	0.022	DOE 1992
Lead	0.045	DOE 1992
Mercury	0.9	DOE 1992
Pentachlorophenol	0.046	DOE 1992
Zinc	1.5	DOE 1992

Table D-5. Average Radionuclide Concentrations (Pci/g)
Detected in 100-H Area Vegetation Samples from 1981 to 1992,
as reported by Schmidt, et al., (1993).

Year	Co-60	Sr-90	Cs-137	Pu-238	Pu-239/240
1981	6.8 E-01	NR	1.5 E-01	NR	NR
1982	NR	NR	NR	NR	NR
1983	1.3 E-01	NR	9.0 E-02	NR	NR
1984	1.8 E-01	2.0 E-00	1.3 E+01	2.0 E-04	1.7 E-03
1985	2.0 E-01	6.0 E-02	4.5 E-02	1.0 E-04	5.1 E-04
1986	2.2 E-01	5.3 E-01	1.3 E+00	1.3 E-04	4.4 E-05
1987	2.6 E-01	2.6 E-01	1.0 E-01	3.5 E-05	2.7 E-04
1988	9.0 E-01	3.9 E-01	1.5 E-01	2.0 E-04	1.5 E-04
1989	6.5 E-01	5.2 E-02	2.1 E-01	8.5 E-05	1.5 E-04
1990	< 1.3 E-01	1.1 E-02	6.6 E-02	< 1.4 E-04	3.0 E-04
1991	< 2.8 E-02	5.7 E-02	3.0 E-02	4.5 E-05	5.7 E-04
1992	< 2.0 E-02	6.7 E-02	< 7.7 E-03	< 1.5 E-06	< 1.3 E-04
NR = Not Reported.					

APPENDIX E

TABLES OF INTAKE SUMMARIES FOR
THE 100-HR-1 OPERABLE UNIT

References

EPA, 1992, *Health Effects Assessment Summary Tables: Annual FY-1992*, OHEA/ECAD-CIN-821, March 1992, U.S. Environmental Protection Agency, Office of Emergency and Residential Response, Washington, D.C.

EPA 1993, *Integrated Risk Information System (IRIS)*, data File, U.S Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY
LEFT BLANK

Table E-1a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	5.3E+05	4.4E+03	9.6E+03	1.0E+04	8.4E+01	6.2E+01
Cobalt-60	4.3E+04	3.6E+02	7.9E+02	8.3E+02	6.9E+00	5.1E+00
Europium-152	7.0E+05	5.8E+03	1.3E+04	1.3E+04	1.1E+02	8.1E+01
Europium-154	1.2E+05	9.6E+02	2.1E+03	2.2E+03	1.8E+01	1.4E+01
Europium-155	5.3E+03	4.4E+01	9.6E+01	1.0E+02	8.4E-01	6.1E-01
Plutonium-238	3.7E+02	3.1E+00	6.7E+00	7.1E+00	5.9E-02	4.3E-02
Plutonium-239/240	8.7E+03	7.2E+01	1.6E+02	1.7E+02	1.4E+00	1.0E+00
Potassium-40	1.7E+04	1.4E+02	3.1E+02	3.3E+02	2.7E+00	2.0E+00
Radium-226	1.0E+03	8.5E+00	1.9E+01	2.0E+01	1.6E-01	1.2E-01
Strontium-90	4.6E+04	3.8E+02	.a	8.8E+02	7.3E+00	.a
Thorium-228	1.2E+03	1.0E+01	2.3E+01	2.4E+01	2.0E-01	1.5E-01
Uranium-233/234	7.0E+02	5.8E+00	1.3E+01	1.3E+01	1.1E-01	8.1E-02
Uranium-238	8.0E+02	6.7E+00	1.5E+01	1.5E+01	1.3E-01	9.4E-02

aNot an external exposure hazard.

Table E-1b. Summary of Intakes for Radioactive Contaminants in 2018
at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	2.9E+05	2.4E+03	5.3E+03
Cobalt-60	1.5E+03	1.2E+01	2.7E+01
Europium-152	1.8E+05	1.6E+03	3.4E+03
Europium-154	1.5E+04	1.2E+02	2.7E+02
Europium-155	1.5E+02	1.3E+00	2.8E+00
Plutonium-238	3.0E+02	2.5E+00	5.5E+00
Plutonium-239/240	8.6E+03	7.3E+01	1.6E+02
Potassium-40	1.7E+04	1.4E+02	3.1E+02
Radium-226	1.0E+03	8.5E+00	1.9E+01
Strontium-90	2.4E+04	2.1E+02	_a
Thorium-228	9.9E-02	8.3E-04	1.8E-03
Uranium-233/234	6.9E+02	5.8E+00	1.3E+01
Uranium-238	7.9E+02	6.7E+00	1.5E+01
aNot an external exposure hazard.			

Table E-1c. Summary of Intakes for Non-Radioactive Contaminants at the 116-H-1 Trench.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)		Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)	
	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic
arsenic	4.7E-04	5.9E-05	-[a]	6.8E-08[b]	9.1E-06	1.1E-06	-[a]	1.4E-09[b]
benzo(a)pyrene	-[a]	1.3E-06	-[a]	-[a]	-[a]	2.4E-08	-[a]	-[a]

[a]No RfD or SF available to evaluate this pathway.
[b]Inhalation intakes of arsenic account for 30% absorption.

Table E-2a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-2 Trench.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	7.0E+04	5.8E+02	1.3E+03	1.3E+03	1.1E+01	8.1E+00
Cobalt-60	9.9E+02	8.2E+00	1.8E+01	1.9E+01	1.6E-01	1.2E-01
Europium-152	1.6E+04	1.3E+02	2.9E+02	3.0E+02	2.5E+00	1.8E+00
Europium-154	2.4E+03	2.0E+01	4.3E+01	4.5E+01	3.8E-01	2.8E-01
Europium-155	3.4E+02	2.8E+00	6.2E+00	6.6E+00	5.5E-02	4.0E-02
Potassium-40	1.7E+04	1.4E+02	3.1E+02	3.3E+02	2.7E+00	2.0E+00
Radium-226	6.6E+02	5.5E+00	1.2E+01	1.3E+01	1.0E-01	7.7E-02
Strontium-90	6.4E+04	5.4E+02	_a	1.2E+03	1.0E+01	_a
Thorium-228	8.3E+02	6.9E+00	1.5E+01	1.6E+01	1.3E-01	9.7E-02
Thorium-232	4.6E+02	3.8E+00	8.4E+00	8.8E+00	7.3E-02	5.4E-02
Uranium-238	7.1E+02	5.9E+00	1.3E+01	1.4E+01	1.1E-01	8.3E-02

a Not an external exposure hazard.

Table E-2b. Summary of Intakes for Radioactive Contaminants in 2018 at the 116-H-2 Trench.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	3.8E+04	3.2E+02	7.0E+02
Cobalt-60	3.3E+01	2.8E-01	6.1E-01
Europium-152	4.1E+03	3.5E+01	7.6E+01
Europium-154	2.9E+02	2.5E+00	5.4E+00
Europium-155	9.2E+00	7.8E-02	1.7E-01
Potassium-40	1.7E+04	1.4E+02	3.1E+02
Radium-226	6.4E+02	5.4E+00	1.2E+01
Strontium-90	3.4E+04	2.9E+02	_a
Thorium-228	6.5E-02	5.5E-04	1.2E-03
Thorium-232	4.5E+02	3.8E+00	8.4E+00
Uranium-238	7.0E+02	5.9E+00	1.3E+01
[a] Not an external exposure hazard.			

Table E-3a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-3 French Drain.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	1.9E+05	1.6E+03	3.5E+03	3.7E+03	3.0E+01	2.2E+01
Cobalt-60	1.7E+04	1.4E+02	3.1E+02	3.3E+02	2.7E+00	2.0E+00
Europium-152	4.2E+04	3.5E+02	7.7E+02	8.1E+02	6.7E+00	4.9E+00
Europium-154	6.3E+03	5.3E+01	1.2E+02	1.2E+02	1.0E+00	7.4E-01
Europium-155	2.9E+02	2.4E+00	5.3E+00	5.5E+00	4.6E-02	3.4E-02
Plutonium-239/240	3.5E+02	3.0E+00	6.5E+00	6.8E+00	5.7E-02	4.1E-02
Potassium-40	1.3E+04	1.1E+02	2.4E+02	2.5E+02	2.1E+00	1.5E+00
Thorium-228	7.6E+02	6.4E+00	1.4E+01	1.5E+01	1.2E-01	8.9E-02
Thorium-232	5.8E+02	4.8E+00	1.1E+01	1.1E-01	9.2E-02	6.8E-02
Uranium-238	7.6E+02	6.4E+00	1.4E+01	1.5E+01	1.2E-01	8.9E-02

Table E-3b. Summary of Intakes for Radioactive Contaminants in 2018
at the 116-H-3 French Drain.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Cesium-137	1.0E+05	8.8E+02	1.9E+03
Cobalt-60	5.3E+02	4.5E+00	9.8E+00
Europium-152	1.1E+04	9.3E+01	2.0E+02
Europium-154	8.1E+02	6.8E+00	1.5E+01
Europium-155	8.1E+00	6.8E-02	1.5E-01
Plutonium-239/240	3.5E+02	3.0E+00	6.5E+00
Potassium-40	1.3E+04	1.1E+02	2.4E+02
Thorium-228	6.0E-02	5.1E-04	1.1E-03
Thorium-232	5.7E+02	4.8E+00	1.1E+01
Uranium-238	7.5E+02	6.4E+00	1.4E+01

Table E-4a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Americium-241	9.5E+02	7.9E+00	1.7E+01	1.8E+01	1.5E-01	1.1E-01
Cesium-134	7.2E+03	6.1E+01	1.3E+02	1.4E+02	1.2E+00	8.3E-01
Cesium-137	2.6E+06	2.2E+04	4.8E+04	5.0E+04	4.2E+02	3.0E+02
Cobalt-60	2.9E+06	2.4E+04	5.3E+04	5.5E+04	4.6E+02	3.3E+02
Europium-152	2.2E+07	1.9E+05	4.1E+05	4.3E+05	3.6E+03	2.6E+03
Europium-154	7.4E+06	6.2E+04	1.4E+05	1.4E+05	1.2E+03	8.5E+02
Europium-155	8.6E+05	7.3E+03	1.6E+04	1.7E+04	1.4E+02	9.9E+01
Nickel-63	2.3E+07	2.0E+05	_a	4.5E+05	3.8E+03	_a
Plutonium-238	8.8E+03	7.5E+01	1.6E+02	1.7E+02	1.4E+00	1.0E+00
Plutonium-239/240	2.6E+05	2.2E+03	4.8E+03	5.0E+03	4.2E+01	3.0E+01
Potassium-40	4.3E+04	3.6E+02	7.9E+02	8.3E+02	6.9E+00	5.1E+00
Radium-226	8.5E+02	7.1E+00	1.6E+01	1.6E+01	1.4E-01	1.0E-01
Strontium-90	3.1E+05	2.6E+03	_a	5.9E+03	5.0E+01	_a
Thorium-228	1.1E+03	8.9E+00	1.9E+01	2.0E+01	1.7E-01	1.2E-01
Thorium-232	5.4E+02	4.5E+00	9.8E+00	1.0E+01	8.6E-02	6.3E-02
Uranium-238	6.1E+03	5.2E+01	1.1E+02	1.2E+02	9.9E-01	7.0E-01
Zirconium-95	7.4E+02	6.1E+00	1.3E+01	1.4E+01	1.2E-01	8.6E-02

a Not an external exposure hazard.

Table E-4b. Summary of Intakes for Radioactive Contaminants in 2018 at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Americium-241	9.0E+02	7.6E+00	1.7E+01
Cesium-134	1.1E+00	9.6E-03	2.1E-02
Cesium-137	1.4E+06	1.2E+04	2.7E+04
Cobalt-60	9.3E+04	7.9E+02	1.7E+03
Europium-152	6.0E+06	5.0E+04	1.1E+05
Europium-154	9.5E+05	8.0E+03	1.8E+04
Europium-155	2.3E+04	1.9E+02	4.2E+02
Nickel-63	1.9E+07	1.6E+05	_a
Plutonium-238	7.2E+03	6.1E+01	1.3E+02
Plutonium-239/240	2.6E+05	2.2E+03	4.8E+03
Potassium-40	4.3E+04	3.6E+02	7.9E+02
Radium-226	8.4E+02	7.1E+00	1.5E+01
Strontium-90	1.6E+05	1.4E+03	_a
Thorium-228	8.4E-02	7.1E-04	1.6E-03
Thorium-232	5.3E+02	4.5E+00	9.8E+00
Uranium-238	6.1E+03	5.2E+01	1.1E+02
Zirconium-95	1.4E-42	1.2E-44	2.5E-44
aNot an external exposure hazard.			

Table E-4c. Summary of Intakes for Non-Radioactive Contaminants at the 116-H-7 Retention Basin.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)		Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)	
	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic
Arsenic	5.9E-04	7.3E-05	.a	2.9E-07	1.1E-05	1.4E-06	.a	5.5E-09
Chromium VI	3.5E-04	.b	.a	1.7E-07	6.8E-06	.b	.a	3.3E-09

aNo RfD or SF available to evaluate this pathway.
bNot classified as a carcinogen or not carcinogenic via this exposure route or pathway.

Table E-5a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Potassium-40	2.0E+04	1.6E+02	3.6E+02	3.8E+02	3.1E+00	2.3E+00
Radium-226	8.4E+02	7.0E+00	1.5E+01	1.6E+01	1.3E-01	9.8E-02
Thorium-228	1.6E+03	1.3E+01	2.9E+01	3.0E+01	2.5E-01	1.8E-01
Thorium-232	9.9E+02	8.2E+00	1.8E+01	1.9E+01	1.6E-01	1.2E-01
Uranium-238	6.2E+02	5.1E+00	1.1E+01	1.2E+01	9.9E-02	7.2E-02

Table E-5b. Summary of Intakes for Radioactive Contaminants in 2018 at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Potassium-40	1.9E+04	1.6E+02	3.6E+02
Radium-226	8.2E+02	7.0E+00	1.5E+01
Thorium-228	1.2E-01	·1.1E-03	2.3E-03
Thorium-232	9.7E+02	8.2E+00	1.8E+01
Uranium-238	6.1E+02	5.1E+00	1.1E+01

Table E-5c. Summary of Intakes for Non-Radioactive Contaminants at the 116-H-9 Crib.

Contaminant	Frequent-Use Scenario				Occasional-Use Scenario			
	Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)		Soil Ingestion (mg/kg-d)		Fugitive Dust Inhalation (mg/kg-d)	
	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic
Barium	8.4E-03	-b	2.1E-05	-b	1.6E-04	-b	4E-07	-b
Beryllium	5.9E-05	7.3E-06	-a	2.9E-08	1.1E-06	1.4E-07	-a	5.5E-10
Chromium VI	1.4E-03	-b	-a	7E-07	2.7E-05	-b	-a	1.3E-08
Manganese	4.0E-02	-b	9.5E-05	-b	7.3E-04	-b	1.8E-06	-b
Vanadium	4.9E-03	-b	-a	-a	9.3E-05	-b	-a	-b

aNo RfD or SF available to evaluate this pathway.
bNot classified as a carcinogen or not carcinogenic via this exposure route or pathway.

WHC-SD-EN-RA-004, Rev. 0

Table E-6a. Summary of Intakes for Radioactive Contaminants in 1992 at the Process Effluent Pipelines.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
SOIL						
Cesium-137	4.5E+01	3.7E-01	7.8E-01	8.6E-01	7.1E-03	5.2E-03
Cobalt-60	5.0E+01	4.2E-01	8.7E-01	9.6E-01	8.0E-03	5.8E-03
Europium-152	1.4E+02	1.2E+00	2.5E+00	2.8E+00	2.3E-02	1.7E-02
Europium-154	1.0E+02	8.7E-01	1.8E+00	2.0E+00	1.7E-02	1.2E-02
Uranium[b]	3.9E+02	3.3E+00	6.9E+00	7.5E+00	6.3E-02	4.6E-02
SLUDGE						
Cesium-134	7.2E+03	6.0E+01	1.3E+02	1.4E+02	1.2E+00	8.5E-01
Cesium-137	3.8E+06	3.2E+04	7.0E+04	7.3E+04	6.1E+02	4.5E+02
Cobalt-60	1.5E+07	1.2E+05	2.7E+05	2.8E+05	2.4E+03	1.7E+03
Europium-152	3.4E+07	2.9E+05	6.3E+05	6.6E+05	5.5E+03	4.0E+03
Europium-154	7.4E+06	6.2E+04	1.4E+05	1.4E+05	1.2E+03	8.7E+02
Europium-155	8.6E+05	7.3E+03	1.6E+04	1.7E+04	1.4E+02	1.0E+02
Nickel-63	2.3E+07	2.0E+05	_a	4.5E+05	3.8E+03	_a
Plutonium-238	1.3E+04	1.1E+02	2.3E+02	2.4E+02	2.0E+00	1.5E+00
Plutonium-239/240	3.0E+05	2.5E+03	5.5E+03	5.8E+03	4.8E+01	3.5E+01
Strontium-90	1.2E+06	1.0E+04	_a	2.4E+04	2.0E+02	_a
Uranium[b]	6.1E+03	5.1E+01	1.1E+02	1.2E+02	9.9E-01	7.2E-01

[a]Not an external exposure hazard.
[b]Assumed to be uranium-238 (see Chapter 2).

Table E-6b. Summary of Intakes for Radioactive Contaminants in 2018
at the Process Effluent Pipelines.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
SOIL			
Cesium-137	2.4E+01	2.1E-01	4.5E-01
Cobalt-60	1.6E+00	1.4E-02	3.0E-02
Europium-152	3.8E+01	3.2E-01	7.1E-01
Europium-154	1.3E+01	1.1E-01	2.5E-01
Uranium[b]	3.9E+02	3.3E+00	7.2E+00
SLUDGE			
Cesium-134	1.1E+00	9.6E-03	2.1E-02
Cesium-137	2.1E+06	1.8E+04	3.8E+04
Cobalt-60	4.8E+05	4.1E+03	8.9E+03
Europium-152	9.0E+06	7.6E+04	1.7E+05
Europium-154	9.5E+05	8.0E+03	1.8E+04
Europium-155	2.3E+04	1.9E+02	4.2E+02
Nickel-63	1.9E+07	1.6E+05	_a
Plutonium-238	1.0E+04	8.7E+01	1.9E+02
Plutonium-239/240	3.0E+05	2.5E+03	5.5E+03
Strontium-90	6.6E+05	5.6E+03	_a
Uranium[b]	6.1E+03	5.1E+01	1.1E+02

[a]Not an external exposure hazard.
[b]Assumed to be uranium-238 (see Chapter 2).

Table E-7a. Summary of Intakes for Radioactive Contaminants in 1992 at the 116-H-7 Sludge Burial Trench.

Contaminant	Frequent-Use Scenario			Occasional-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Europium-154	7.9E+01	6.6E-01	1.4E+00	1.5E+00	1.3E-02	9.2E-03

Table E-7b. Summary of Intakes for Radioactive Contaminants in 2018 at the
116-H-7 Sludge Burial Trench.

Contaminant	Frequent-Use Scenario		
	Soil Ingestion (pCi)	Fugitive Dust Inhalation (pCi)	External Exposure (pCi-yr/g)
Europium-154	1.0E+01	8.5E-02	1.8E-01

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX F

EVALUATION OF EXTERNAL RADIATION EXPOSURE
UNDER A CURRENT OCCASIONAL-USE SCENARIO

References:

Argonne, 1992, *RESRAD, Version 4.6*, Argonne National Laboratory, Argonne, Illinois.

EPA, 1989, *Risk Assessment Methodology: Environment Impact Statement for NESHAPS
     Radionuclides. Volume I: Background Information Document*, EPA/520/1-89/005, U.S.
     Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

EPA, 1992, *Health Effects Assessment Summary Tables: Annual FY-1992*, OHEA/ECAO-CIN-821
     March 1992, U.S. Environmental Protection Agency, Office of Emergency and Remedial
     Response, Washington, D.C.

Woodruff, R.K., R.W. Hanf, and R.E. Lundren, 1991, *Hanford Site Environmental Report for
     Calendar Year 1991*, PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

TABLES:

**THIS PAGE INTENTIONALLY
LEFT BLANK**

F-1.0 EXTERNAL EXPOSURE EVALUATION METHODOLOGY

F-1.1 PROBLEM DEFINITION

The method for evaluating radionuclide risks via the external exposure pathway is likely to provide unrealistic (conservative) risk estimates. Two characteristics of the qualitative risk assessment methodology account for this conservatism: the use of EPA slope factors, and the use of maximum concentrations within the top 15 ft.

The use of external exposure slope factors is only appropriate when contaminant conditions can be represented by an infinite slab source without cover (EPA 1992). For radionuclides that emit high energy gamma rays (e.g., cobalt-60 and cesium-137), this condition is satisfied if contamination is uniformly distributed from the ground surface to a depth of nearly 1 m (3.3 ft), and covers an area of approximately 1200 m². The extent to which these conditions are not satisfied is directly related to the over estimate of the risk.

The use of data from samples as deep as 15 ft is based on the assumption that 15 ft is the depth of soil that could be excavated and distributed at the soil surface [WAC 173-340-740(6)(c)], such as during the building of a basement. This assumption precludes accounting for the existence of a clean cover (if one currently exists). Under this assumption, risk values calculated for the external exposure pathway may be unrepresentative of current site conditions.

F-1.2 APPROACH

In evaluating the current occasional-use scenario, it is appropriate that a more limited set of data representing samples from 0 to 1.8 m (0 to 6 ft) be used for comparison to risk-based concentrations. This approach intends to compensate for one conservative characteristics of the external exposure analysis (i.e., the choice of a maximum contaminant concentration). It does not, however, compensate for the potential conservatism associated with external exposure slope factors. Justification for using this approach is described as follows.

Under current site conditions, institutional controls prevent the inadvertent intrusion into a contaminated zone such that any clean soil cover is maintained. Consequently, a more realistic evaluation of a current exposure should account for the presence of a clean cover, and the size of a contaminated zone. Unfortunately, available data are not sufficient to provide an accurate profile of contaminant conditions. For example, although one borehole may indicate that contaminants are not present above 1 m, it may not be a good assumption that there is a clean cover of 1 m over the whole site because of the limited sampling data. Unless there is site-specific information indicating that clean backfill material was deposited over the whole site, borehole data should not be used as evidence of a clean cover.

One way that the shielding effect of soil can be accounted for at all sites is to recognize that radionuclides below a certain depth will not contribute to risk because this thickness of soil is sufficient to shield against any likely radionuclide concentrations. As a result, radionuclide concentration data from samples below a certain depth can be ignored.

For the purpose of this evaluation, 1.8 m (6 ft) of soil cover is assumed to provide sufficient shielding from external exposure to gamma radiation. Consequently, the depth range evaluated for the current occasional-use scenario (accounting for shielding) is 0 to 1.8 m (0 to 6 ft) below ground surface.

Two meters of clean soil provides sufficient shielding such that it is nearly impossible for a contaminated zone to have radionuclide concentrations high enough to provide a lifetime incremental cancer risk (ICR) of 10^{-6} or more. Table F-1 provides the radionuclide concentrations that would have to be present in an infinite slab with 1.8 m (6 ft) of clean cover such that a person with continuous exposure to the site (for 30 yr) would incur an ICR of 10^{-6}. Since it is extremely unlikely (if not nearly impossible) for environmental contamination to exist at these activity concentrations, it is reasonable that data from samples taken below 1.8 m (6 ft) be dismissed for evaluation of external exposure risks under a current occasional-use scenario.

The values presented in Table F-1 were generated with the use of the RESRAD code (Argonne 1992). RESRAD provides external exposure dose rates associated with radionuclide concentrations. The ratio of these two values allows one to determine the radionuclide concentrations required to provide any specified dose rate (or cancer risk value) as follows:

$$RBC \quad = \quad 10^{-6}/[(\text{unit dose rate}) \times 6.2 \times 10^{-7}/\text{mrem} \times 30 \text{ yr}]$$

$$= \quad 5.4 \times 10^{-2} \text{ (mrem/yr)/(unit dose rate)}$$

where:

	RBC	=	Risk-based concentration (pCi/g) associated with a 10^{-6} lifetime incremental cancer risk
	unit dose rate	=	dose rate per unit concentration (radionuclide specific (mrem/yr per pCi/g); calculated using RESRAD (Argonne 1992)

The risk factor used to relate dose to risk is $6.2 \times 10^{-7}/\text{mrem}$, as recommended by EPA (1989) for estimating lifetime cancer (incidence) risk.

RESRAD requires the selection of several input parameters. The pertinent input parameters for this analysis are as follows: cover depth (1.8 m), density of cover material (1.6 g/m³), shielding factor (0), shape factor (1), and fraction of time spent outdoors (1). This last parameter corresponds to a continuous exposure. All other parameter values used are RESRAD default values.

It is noted that even 1 m (3.3 ft) is likely to provide sufficient shielding from any likely radionuclide concentration. For example, an infinite slab with 1 m of clean cover would have to have a uniform concentration of 5.8×10^3 pCi/g of cesium-137 in order to pose a risk of 10^{-6} to the frequent user. However, as noted above, the depth to contamination within a small number of boreholes may not provide a representative estimate of the thickness of the clean

cover for the whole site. Including data from samples down to 1.8 m (6 ft) is intended to compensate for this uncertainty.

This method should not be interpreted as a means of making the external exposure pathway analysis accurate. It simply removes one of the characteristics that makes this analysis unrealistically conservative. This method is still conservative because it considers the maximum detected concentration in the upper 1.8 m (6 ft) as being representative of contaminant conditions, and the use of unadjusted slope factors means that the risk estimates are most appropriate for an infinite slab source.

Radionuclide concentrations from the top 1.8 m (6 ft) can then be compared to risk-based concentrations calculated using occasional-use exposure parameters. This comparison provides a simple means of approximating the external exposure risk, rather than using contaminant concentration data to calculate risk estimates. These risk-based concentrations are presented in Table F-2, and are calculated for target risks of 10^{-4} and 10^{-6}.

F-1.3 ANALYSIS PROCEDURE

Based on this discussion, the external exposure pathway for the occasional-use scenario has been analyzed as follows:

- determine which samples were taken from depths less than 6 ft (i.e., bottom of sample is above 6 ft),
- identify the highest radionuclide concentrations detected in either LFI or historical data for a waste site,
- compare these concentrations with risk-based concentrations (based on occasional-use exposure parameters, and 10^{-4} and 10^{-6} target risks).

If the maximum detected concentrations are less than the 10^{-6} risk-based concentrations (Table F-2), then the risk associated with the external exposure pathway is assumed to be negligible under the current scenario. If a radionuclide's maximum detected concentration exceeds its respective 10^{-6} risk-based concentration, then the ratio of the maximum detected concentration to the risk-based concentration is used to estimate the external exposure risk associated with that radionuclide.

F-1.4 USE OF SURVEY DATA

Radiological survey data or thermoluminescent dosimeter (TLD) data for a waste site provide additional information on the external exposure hazard associated with that site. The environmental monitoring results indicate whether ambient external radiation levels are attributable to background radiation, or if site contamination results in a significant increase above background levels. If monitoring results indicate that the external radiation levels are consistent with background, then it is concluded that the external exposure risk associated with the site is less than 10^{-5} (even if the risk estimate based on soil concentration data is higher).

It is not possible, using survey data, to determine whether the external exposure risk is less than 10^{-5} because this is the approximate risk associated with the fluctuation in natural

background radiation levels. The background external exposure level in the Tri-Cities is approximately 100 mrem/yr (Woodruff et al. 1992). Unless contaminants raise the total dose rate by a significant fraction of this amount (e.g., 50 mrem/yr), this increase can not be detected by field instruments. Under an occasional-use scenario, an increase in the ambient radiation level of 50 mrem/yr would be associated with an ICR of approximately 10^{-5}.

In most cases, radiation survey data will only indicate whether the radiation level is less than background, or (if greater than background) the meter count rate. These data are of insufficient quality to derive dose rates or risk values. Radiation survey data are often intended to only indicate whether or not contamination is present. Survey reports may indicate whether the above background readings are associated with surface contamination or contaminants distributed in soil at depth. It is the latter case which is of interest in this analysis. Surface contamination and contamination at depth can result in external exposures, and the presence of either indicates that the risk via external exposure may be greater than 10^{-5}. However, the presence of surface contamination *alone* indicates that risk calculations (which are based on the assumption of contamination at depth) are inappropriate; such risk values should be viewed with a great deal of skepticism.

TLD data are useful only if the TLDs are in close proximity (within a few meters) to a waste site. TLD data provide dose rates (mrem/yr), and should be compared to background levels in order to determine whether site contaminant contribute to the external exposure levels.

A summary of the additional evaluation of the external exposure pathway for each waste site is provided in the discussion of the threat posed by the site in Chapter 3.

F-2.0 EVALUATION OF EXTERNAL EXPOSURE FOR 100-HR-1

Table F-3 indicates that maximum detected radionuclide concentrations (within the upper 6 ft) exceed risk-based concentrations for one or more radionuclides at the 116-H-1 trench, 116-H-2 trench, 116-H-3 french drain, 116-H-7 retention basin, and 116-H-9 crib. These radionuclides include cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, potassium-40, and thorium-228. [Note: radionuclide concentrations within the diversion/junction box of the process effluent pipelines also exceed risk-based concentrations; however, these data represent contaminated materials within an existing structure, not environmental contamination.] This conclusion is based entirely on maximum concentrations (in the upper 6 ft) from historical data excepting all data for potassium-40, and thorium-228, as well as europium-152 at the 116-H-3 french drain, which are from the LFI.

By comparing the maximum detected and risk-based concentrations, it is possible to estimate the risk associated with each waste site. Using this method, the approximate risks associated with the waste sites noted above are as follows:

- 116-H-1 trench   5E-04
- 116-H-2 trench   2E-05
- 116-H-3 french drain   1E-04
- 116-H-7 retention basin >1E-02
- 116-H-9 crib   2E-06

It is important to note that these risk estimates are based on the extremely conservative assumption that the maximum detected contaminant concentrations (in the upper 6 ft) define a contaminated zone with an area of at least 1200 m^2 and a thickness of at least 1 m (i.e., essentially an infinite slab source).

Table F-4 provides a summary of WHC radiation survey reports for the 100-HR-1 operable unit and indicates that 116-H-1, 116-H-2, and 116-H-7 basin are the only sites which exhibit above background surface radiation levels. A WHC walking-stick survey of 116-H-1, 116-H-2, and 116-H-9 is provided in Table F-5. This survey indicates that there is a surface contamination area associated with the 116-H-1 trench but no elevated radiation levels within the trench itself. The 116-H-2 trench has detectable surface radiation within the trench itself. The 116-H-9 crib does not have elevated levels of surface radiation.

The survey data for 116-H-2 is in agreement with risk calculations for determining sites that pose potentially significant risks via the external exposure pathway. For the 116-H-9 crib, the lack of survey evidence for elevated levels of surface contamination is likely due to the fact that potassium-40, a naturally occurring radionuclide, is a primary risk-driver. Background levels of this radionuclide probably prevented detection of the thorium-228 identified at this site in the upper 6 ft of soil. The discrepancy between survey data and historical data at the 116-H-1 trench can probably be ascribed to additional fill being added since 1978.

These survey data are only useful in determining where contamination is present; they cannot be used to estimate risk values.

Table F-1. Concentrations of Various Gamma Emitting Radionuclides Required to Provide a 10^{-6} Lifetime Incremental Cancer Risk via External Exposure[a].

Radionuclide	Risk-Based Concentration[b] (pCi/g)
Cobalt-60	1.5E+06
Cesium-134	6.9E+07
Cesium-137	2.3E+08
Europium-152	2.1E+06
Europium-154	3.5E+06
Radium-226	6.2E+05
Thorium-228	1.4E+04

[a]Assumes an infinite slab source with 6 ft of clean cover, and continuous exposure for 30 yr.
[b]Accounts for contribution of radioactive daughter products. Concentrations calculated with the use of RESRAD (Argonne 1992).

Note: Risk-based concentrations for other radionuclides would be higher than those presented here.

Table F-2. Risk Based Radionuclide Concentrations for the
External Exposure Pathway Based on an Occasional-Use Scenario (1992)
without Shielding.

Radionuclides	Concentration[a] at ICR = 10^{-6} (pCi/g)	Concentration[a] at ICR = 10^{-4} (pCi/g)
Americium-241	1.3E+03	1.3E+05
Cesium-134	1.3E+00	1.3E+02
Cesium-137	3.3E+00	3.3E+02
Cobalt-60	7.6E-01	7.6E+01
Europium-152	1.8E+00	1.8E+02
Europium-154	1.6E+00	1.6E+02
Europium-155	1.1E+02	1.1E+04
Plutonium-238	2.3E+05	2.3E+07
Plutonium-239/240	2.4E+05[b]	2.4E+07[b]
Potassium-40	1.2E+01	1.2E+03
Radium-226	1.1E+00	1.1E+02
Technetium-99	1.1E+07	1.1E+09
Thorium-228	1.2E+00	1.2E+02
Thorium-232	2.5E+05	2.5E+07
Uranium-233/234	1.6E+05	1.6E+07
Uranium-235	2.7E+01	2.7E+03
Uranium-238	1.8E+02	1.8E+04
Zirconium-95	2.6E+00	2.6E+02

[a]Assumes radionuclides are uniformly distributed in soil (no shielding)
[b]Plutonium-240 slope factor was used for calculation
ICR = Lifetime incremental cancer risk

Note: Risk-based concentrations are not provided for carbon-14, nickel-63, strontium-90, and tritium (H-3) because they are not gamma emitters.

Table F-3. Summary of Maximum Concentrations of Radionuclides in 1992 at the
100-HR-1 Waste Sites. (Sheet 1 of 4)

Radionuclide	Depth (ft)	Sites with LFI and Historical Data					Sites with Historical Data Only		
		116-H-1 Trench (pCi/g)	116-H-2 Trench (pCi/g)	116-H-3 Drain (pCi/g)	116-H-7 Basin (pCi/g)	116-H-9 Crib (pCi/g)	Process Effluent Pipeline (soil) (pCi/g)	Process Effluent Pipeline[a] (sludge) (pCi/g)	116-H-7 Trench (pCi/g)
Americium-241	0-6	-	-	-	-	-	-	-	-
	6-15	0.2(L)	-	-	0.72 (L)	-	-	-	-
	>15	0.077(L)	-	-	-	-	-	-	-
Carbon-14	0-6	-	-	-	ND	-	ND	-	-
	6-15	ND	-	-	33 (L)	-	_b	-	-
	>15	15 (L)	-	-	34 (L)	-	-	-	-
Cesium-134	0-6	0.00017 (H)	0.00038 (H)	ND	5.5^d (H)	-	ND	-	-
	6-15	0.00016 (H)	0.00015 (H)	ND	0.00064 (H)	-	_b	-	-
	>15	0.00018 (H)	-	-	ND	-	-	5.5^d (H)	-
Cesium-137	0-6	400^c (H)	53^d (H)	150^d (H)	2000^c (H)	-	0.034 (H)	-	-
	6-15	32^d (H,L)	0.064 (H)	76^d (H)	46^d (H)	-	_b	-	-
	>15	360^c (H)	-	-	57^d (H)	0.29 (L)	-	2900^c (H)	-
Cobalt-60	0-6	33^d (H)	0.75 (H)	13^d (H)	2100^c (H)	-	0.038 (H)	-	-
	6-15	2.5^d (L)	0.078 (H)	0.38 (L)	36^d (L)	-	_b	-	-
	>15,	52^d (H)	-	0.13 (H)	36^d (H)	-	-	11,000^c (H)	-
Europium-152	0-6	530^c (H)	12^d (H)	32^d (L)	17,000^c (H)	-	0.11 (H)	-	-
	6-15	54^d (L)	0.31 (H)	0.88 (H)	260^c (L)	-	_b	-	-
	>15	930^c (L)	-	-	210^c (H)	-	-	26,000^c (H)	-
Europium-154	0-6	88^d (H)	1.8^d (H)	4.8^d (H)	5700^c (H)	-	0.079 (H)	-	-
	6-15	5.4^d (L)	0.037 (H)	0.31 (H)	37^d (L)	-	_b	-	0.06 (H)
	>15	710^c (H)	-	-	37^d (H)	-	-	5700^c (H)	-

Table F-3. Summary of Maximum Concentrations of Radionuclides in 1992 at the
100-HR-1 Waste Sites. (Sheet 2 of 4)

Radionuclide	Depth (ft)	Sites with LFI and Historical Data					Sites with Historical Data Only		
		116-H-1 Trench (pCi/g)	116-H-2 Trench (pCi/g)	116-H-3 Drain (pCi/g)	116-H-7 Basin (pCi/g)	116-H-9 Crib (pCi/g)	Process Effluent Pipeline (soil) (pCi/g)	Process Effluent Pipeline[a] (sludge) (pCi/g)	116-H-7 Trench (pCi/g)
Europium-155	0-6	4.4 (H)	0.26 (H)	0.093 (H)	650^d (H)	-	0.039 (H)	-	-
	6-15	0.035 (H)	0.022 (HO)	4.8 (H)	1.1 (H)	-	-^{b}	-	0.015 (H)
	>15	9.7 (H)	-	-	2.5 (H)	-	-	660^d (H)	-
Nickel-63	0-6	-	-	-	18,000 (H)	-	-	-	-
	6-15	-	-	-	-	-	-	-	-
	>15	-	-	-	-	-	-	18,000 (H)	-
Plutonium-238	0-6	0.28 (H)	ND	-	6.8 (H)	-	0.024 (H)	-	-
	6-15	ND	ND	ND	0.70 (H)	-	-^{b}	-	-
	>15	0.31 (H)	-	-	0.26 (H)	-	-	9.7 (H)	-
Plutonium-239/240	0-6	6.6 (H)	0.13 (H)	-	200 (H)	-	0.14 (H)	-	-
	6-15	0.64 (L)	ND	0.27 (H)	1.9 (H)	-	-^{b}	-	-
	>15	1.8 (H)	-	-	3.2 (H)	-	-	230 (H)	-
Potassium-40	0-6	-	-	-	7.2 (L)	15^d (L)	-	-	-
	6-15	13^d (L)	13^d (L)	9.8 (L)	33^d (L)	-	-	-	-
	>15	13^d (L)	-	8.8 (L)	11 (L)	11 (L)	-	-	-
Radium-226	0-6	-	-	-	0.29 (L)	0.64 (L)	-	-	-
	6-15	0.78 (L)	0.5 (L)	-	0.65 (L)	-	-	-	-
	>15	0.85 (L)	-	0.45 (L)	0.44 (L)	0.71 (L)	-	-	-
Strontium-90	0-6	35 (H)	49 (H)	-	240 (H)	-	0.088 (H)	-	-
	6-15	6.2 (L)	8.7 (H)	0.38 (H)	12 (H)	-	-^{b}	-	0.26 (H)
	>15	55 (H)	-	-	6.4 (H)	-	-	950 (H)	-
Technetium-99	0-6	-	-	-	-	-	-	-	-
	6-15	0.25 (L)	-	-	0.26 (L)	-	-	-	-
	>15	0.67 (L)	-	-	-	-	-	-	-

F-9

WHC-SD-EN-RA-004, Rev. 0

Table F-3. Summary of Maximum Concentrations of Radionuclides in 1992 at the
100-HR-1 Waste Sites. (Sheet 3 of 4)

Radionuclide	Depth (ft)	Sites with LFI and Historical Data					Sites with Historical Data Only		
		116-H-1 Trench (pCi/g)	116-H-2 Trench (pCi/g)	116-H-3 Drain (pCi/g)	116-H-7 Basin (pCi/g)	116-H-9 Crib (pCi/g)	Process Effluent Pipeline (soil) (pCi/g)	Process Effluent Pipeline[a] (sludge) (pCi/g)	116-H-7 Trench (pCi/g)
Thorium-228	0-6	-	-	-	0.41 (L)	1.2[d] (L)	-	-	-
	6-15	0.95 (L)	0.63 (L)	0.58 (L)	0.81 (L)	-	-	-	-
	>15	0.75 (L)	-	0.57 (L)	0.46 (L)	1.1 (L)	-	-	-
Thorium-232	0-6	-	-	-	0.41 (L)	0.75 (L)	-	-	-
	6-15	-	0.35 (L)	0.44 (L)	-	-	-	-	-
	>15	0.89 (L)	-	0.26 (L)	0.44 (L)	1.1 (L)	-	-	-
Tritium	0-6	-	4.5 (H)	-	150 (H)	-	18 (H)	-	-
	6-15	0.39 (H)	18 (H)	1.8 (H)	6.9 (H)	-	-[b]	-	-
	>15	0.26 (H)	-	-	17 (H)	-	-	650 (H)	-
Uranium-233/234	0-6	-	-	-	-	-	-	-	-
	6-15	0.53 (L)	-	-	-	-	-	-	-
	>15	0.62 (L)	-	0.35 (L)	-	-	-	-	-
Uranium-235	0-6	-	-	-	-	-	-	-	-
	6-15	-	-	-	-	-	-	-	-
	>15	0.0016 (L)	-	-	-	-	-	-	-
Uranium-238	0-6	-	-	-	4.7 (H)	0.47 (L)	0.3 (H)	-	-
	6-15	0.61 (L)	0.54 (L)	0.58 (L)	0.68 (L)	-	-[b]	-	-
	>15	0.58 (L)	-	0.44 (L)	0.53 (L)	0.45 (L)	-	4.7 (H)	-
Zirconium-95	0-6	-	-	-	0.56 (L)	-	-	-	-
	6-15	-	-	-	-	-	-	-	-
	>15	-	-	-	-	-	-	-	-

WHC-SD-EN-RA-004, Rev. 0

Table F-3. Summary of Maximum Concentrations of Radionuclides in.1992 at the
100-HR-1 Waste Sites. (Sheet 4 of 4)

[a] Process Effluent Pipeline sludge is present within existing structures.
[b] Value for 0-6 ft. could be at any depth within top 15 ft.
[c] Shaded area indicates maximum concentration exceeds external risk-based concentration at 1E-04 risk.
[d] Shaded area indicates maximum concentration exceeds external risk-based concentration at 1E-06 risk.

(H) = Historical Data (Dorian & Richards 1978).
(L) = LFI Data, 1992.
ND = Not detected.
- = Not analyzed.

Table F-4. Summary of Radiation Surveys and TLD Data for 100-HR-1.

Site	Radiation Survey Data[a]			TLD Data
	Below Background	Surface Contamination Detected by Survey Instruments	Soil Contamination at Depth Detected by Survey Instruments	
116-H-1 trench	yes	no	no	-
116-H-2 trench	no	yes	-[c]	-
116-H-3 drain	yes	no	no	-
116-H-7 basin	no	yes	-[c]	-
116-H-9 crib	yes	no	no	-
Proc. Eff. Pipe.	-[b]	-[b]	-[b]	-
116-H-7 trench	-[b]	-[b]	-[b]	-
116-H-5 outfall	yes	no	no	-
132-H-3 pump station	-[d]	-[d]	-[d]	-
116-H-6 basin	yes	no	no	-
132-H-2 building	-[d]	-[d]	-[d]	-
132-H-1 stack	-[d]	-[d]	-[d]	-
116-H-4 crib	-[d]	-[d]	-[d]	-

[a] Although surface contamination or soil contamination at depth may be detected, some portion of each site is characterized by below background radiation levels.
[b] No survey data exists for this waste site.
[c] No attempt was made to determine depth profile of contamination.
[d] No specific sampling of these waste sites was performed, some surveys in the general location of these waste sites have detected areas of radiation above background.
- = no information available.
TLD = Thermoluminescent dosimeter.

Westinghouse Hanford Company

RADIATION SURVEY REPORT

Date	Time	Survey Number	F C	Page
25 JAN 92	From 0730 to 1500	111631	ER	1 of 2

Bldg	Area	Room
N/A	100 H	N/A

Description of Job

HPT WALKING STICK RELEASE OF WELLSITES # 116-H-1 / 116-H-2 / 116-H-9 AND ROUTINES OF 5 TRAILERS.

RWP No	Location
N/A	116-H-1 / 116-H-2 / 116-H-9

Check if appropriate. When checked, do not place unrelated information on this record

- [ ] Personnel Contamination
- [ ] CAM/Radiation Alarm
- [ ] Establish Dose Rates
- [ ] Radiation/Contamination Incident
- [ ] High Radiation Level Work
- [x] "Special Survey"
- [ ] Property Release
- [ ] RAM Shipment

Item No.	PER (1)	Description of Work Performed, Radiation Controls, and Measurements	Meter Deflection W/O	Meter Deflection W/C	Dist	C F	beta (non pen) mrad/hr	gamma (pen) mR/hr	neutron mrem/hr	Direct (dpm) beta	Direct (dpm) alpha	Smear 100 cm² beta (d/m)	Smear 100 cm² alpha (d/m)	GROSS mrad/hr
1	-	SITE # 116-H-1 SCA AREA	-	-	-	/	-	-	-	3500	-	-	-	-
2	-	SITE # 116-H-2	-	-	-	/	-	-	-	5000	-	-	-	-
3	-	SITE # 116-H-9	-	-	-	/	-	-	-	<D	-	-	-	-
4	-	TRAILERS AT 199-H46/199-H-47	-	-	-	/	-	-	-	<D	-	<D	-	-
5	-	TRAILER M-0399	-	-	-	/	-	-	-	<D	-	<D	-	-
6	-	TRAILER M-0429	-	-	-	/	-	-	-	<D	-	<D	-	-
7	-	TRAILER M-0421	-	-	-	/	-	-	-	<D	-	<D	-	-
8	-	PERSONNEL	-	-	-	/	-	-	-	<D	-	-	-	-

1 Check for personnel dose rate   [x] Continued on supplemental report form

Instrument(s) Used	[x] GM/P-11	[x] G-M/Pancake	[x] GM PRM/P-11	[x] G-M/P-11	[x] G-M/P-11	[ ]
Serial No.(s)	0993 1656	1595 1819	945 1783	1895 857	921 1719	N/A

ESTIMATED PERSONNEL DOSE RATES

Phase of Work	Based on Measurement(s)	Average Dose Rate	Limit Applying
N/A	N/A	N/A	WBP S E
			W9P N/A E
			WBP S E

Respiratory Protection Worn

- [ ] Supplied Air
- [ ] Filter
- [ ] Other _____
- [x] None

RPT Exposure	Work Location Code	Signed
<0.5	N/A	Michael Vaughan 82782

Did you increase or reduce RWP requirements for this work?
[x] No [ ] Yes Explain on reverse side

Did you attend a pre-job meeting for this work?
[x] N/A [ ] No [ ] Yes

Reviewed By Mabry   Date 27 JAN 92

BD-   J (10-90)

Westinghouse Hanford Company

RADIATION SURVEY REPORT

SUPPLEMENTAL REPORT FORM

Date	Survey No.	F.C.
25 JAN 92	111631	ER

Item No	P E R (1)	Description of Work Performed, Radiation Controls, and Measurements	Meter Deflection		Dist.	C.F.	DOSE RATE			CONTAMINATION LEVELS				
			W/O	W/C			beta (non pen) mrad/hr	gamma (pen) mR/hr	neutron mrem/hr	Direct (dpm)		Smear 100 cm²		
										beta	alpha	beta (d/m)	alpha (d/m)	mrad/hr
9	—	SITE # 116-H-1	—	—	—	—	—	—	—	<D	—	—	—	—

Reviewed By _____ Date 27 JAN 92 _____

F-14

Table F-5. Survey Data for 116-H-1, 116-H-2, and 116-H-9 (Survey Number 111631). (Sheet 2 of 3)

WHC-SD-EN-RA-004, Rev. 0

RADIATION SURVEY REPORT (cont.)

Survey Number **111631** F C **ER** Page 2 of 2

...er Descriptions, Data, and Comment

SITE 116-H-2 WAS ROPED AND POSTED AS AN "SCA" DUE TO CONTAMINATED VEGETATION. SITE 116-H-1 WAS <D β-ϒ, BUT AN SCA WAS FOUND JUST TO THE EAST OF THAT SITE, AND WAS ROPED OFF AND POSTED. SITE 116-H-9 <D β-ϒ. ROUTINGS DONE AT 5 TRAILERS.

SITE CONDITIONS:
DRY WITH VEGETATION

SOLAR BASIN

DIAGRAMS OR SKETCHES

SITE # 116-H-9 <D β-ϒ

H Rx

GATE B
H Rx

SITE # 116-H-2 MARKED AS "SURFACE CONTAMINATION AREA."

SITE CONDITIONS DRY WITH MUCH VEGETATION.

SITE # 116-H-1 <D β-ϒ

MARKED AS "SURFACE CONTAMINATION AREA"

SITE CONDITIONS: DRY + NO VEGETATION.

COLUMBIA RIVER

ADDITIONAL REPORTS COMPLETED

	Log No.		Log No.
Radiological Problem Report		Onsite Radioactive Shipment	
Skin Contamination Survey		Offsite Radioactive Shipment	
Personnel Effects Contamination Report		Routine Radioactive Shipment	
Radiation Survey Report		Sample Counter Log	

U.S. GOVERN... INTING OFFICE: 1991-593-948

Table F-5. Survey Data for 116-H-1, 116-H-2, and 116-H-9 (Survey Number 111631). (Sheet 3 of 3)

WHC-SD-EN-RA-004, Rev. 0

F-15

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX G
DATA ASSESSMENT BASED ON LABORATORY AND FIELD BLANKS

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

LIST OF TABLES

THIS PAGE INTENTIONALLY
LEFT BLANK

Tables G-1 and G-2 show the results of laboratory and field organic blank data assessments, respectively.

G.2 Inorganic Data Evaluation

Inorganic data were compiled and evaluated against field blanks as follows:

- Electronic files containing laboratory reports of sample data were provided by WHC Hanford Environmental Information System (HEIS), the results extracted and compiled into tabular summaries

- Laboratory reports (Form 1's) of sample data not available in an electronic format were obtained from WHC Environmental Data Management Center (EDMC) in Richland, Washington and the data contained in these reports were compiled into the tabular summaries

- Sample results not available electronically or on hard copy were obtained from the data validation reports and compiled into the tabular summaries

- After receipt of data validation reports, tabular summaries were updated as appropriate and assessment of sample results against field blank results was performed using the five times rule.

Table G-3 shows the results of inorganic field blank data assessments.

G.3 Radiochemical Data Evaluation

Radiochemical data were compiled and evaluated against field blanks as follows:

- Sample results were collected from the data validation reports and compiled into a tabular summary

- Laboratory reports (Form 1's) of sample data not available from the data validation reports were obtained from WHC Environmental Data Management Center (EDMC) in Richland, Washington and the data contained in these reports were compiled into the tabular summaries

- After compilation, the tabular summaries were updated as appropriate, according to the data validation reports, and assessment of sample results against field blank results was performed using the five times rule.

Table G-4 shows the results of radiochemistry field blank data assessments.

This appendix explains how validated data were evaluated against laboratory and field blank data prior to their use in the risk assessment. Evaluation was conducted using EPA's data validation guidance (Bleyler 1988a and 1988b) and risk assessment data evaluation guidance (EPA 1989). The evaluation was conducted separately for organic, inorganic and radiochemical results in a step-wise fashion as presented below.

G.1 Organic Data Evaluation

Organic data were first compiled and evaluated against laboratory blanks then field blanks as follows:

- Electronic files containing laboratory results of both samples and associated laboratory blank data were provided by WHC Hanford Environmental Information System (HEIS). Sample and laboratory blank results contained in these files were extracted and compiled into tabular summaries

- Laboratory reports (Form 1's) of both sample and associated laboratory blank data not available in electronic format were obtained from WHC Environmental Data Management Center (EDMC) in Richland, Washington and the data contained in these reports were compiled into the tabular summaries

- Sample results not available electronically or on hard copy were obtained from the validation reports and compiled into the tabular summaries

- Laboratory blank results were identified by the laboratory performing the analysis. Detected results in laboratory blanks were multiplied by a factor of five (ten for compounds considered common laboratory contaminants) and were matched to samples containing similar detected compounds and that were analyzed by the same laboratory which analyzed the blank.

- Detected sample results less than or equal to five or ten times the associated laboratory blank results were qualified as undetected (U).

- After laboratory blank assessment tabular summaries were updated as appropriate, according to the data validation reports. No detects remained in the field blanks.

Upon review of the validation reports, errors were found relating to blank results and associated sample result qualification as follows:

- Data validation report WHC-SD-EN-TI-084 summary tables indicated that naphthalene and 2-methylnaphthalene were undetected in sample B05WV7 while laboratory data reported it detected. The accompanying narrative did not include naphthalene or 2-methylnaphthalene as contaminants detected in the blank evaluation.

G.4 References

Bleyler, R. 1988a, *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*, U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.

Bleyler, R. 1988b, *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses*, U.S. Environmental Protection Agency, Hazardous Site Evaluation Division, Washington, D.C.

EPA, 1989. *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part A; Interim Final*, EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

Table G-1. Organic Laboratory Blank Evaluation Results

ORGANIC COMPOUNDS DETECTED IN LABORATORY BLANKS AND THEIR EFFECT ON ASSOCIATED SAMPLE DATA					
COMPOUND DETECTED	HIGHEST ASSOCIATED LABORATORY BLANK RESULT	FIVE-TIMES or TEN-TIMES LABORATORY BLANK RESULT	SAMPLES AFFECTED	SAMPLE RESULTS	FINAL RESULT
Pyrene	27	135	B05WV8 B05WV9	48 J 85 J	48 JU 85 JU
Acetone	26	260	B05WP5 B05WV5	7 J 13	7 JU 13 U
Chloroform	1	5	B05WP7 B05WP6	2 J 2 J	2 UJ 2 UJ
Methylene chloride	8	80	B05WP5 B05WW7 B05WP7 B05WP6 B05WV5	3 J 3 J 7 10 11	3 JU 3 JU 7 U 10 U 11 U
Di-n-butylphthalate	100	1000	B05WP7 B05WW4 B05WW5 B05WV9 B05WV6 B05WV8 B05WV4	6 J 46 J 48 J 50 J 59 J 68 J 330 J	6 JU 46 JU 48 JU 50 JU 59 JU 68 JU 330 JU
N-nitrosodiphenylamine	46	230	B05WV8	59 J	59 JU

Table G-2. Organic Field Blank Evaluation Results

COMPOUND DETECTED	HIGHEST ASSOCIATED FIELD BLANK RESULT	FIVE-TIMES or TEN-TIMES FIELD BLANK RESULT	SAMPLES AFFECTED	SAMPLE RESULT	FINAL RESULT
Toluene	2	20	B05WV8	1 J	1 JU
			B05WV9	2 J	2 JU
			B05WV3	3 J	3 JU
			B05WV6	4 J	4 JU
			B05WP5	7	7 U
			B05WV5	14	14 U

Table G-3. Inorganic Field Blank Evaluation Results

COMPOUND DETECTED	HIGHEST ASSOCIATED FIELD BLANK RESULT ug/L	FIVE-TIMES CONVERTED BLANK RESULT mg/Kg	SAMPLES AFFECTED	SAMPLE RESULT mg/Kg	FINAL RESULT mg/Kg
Aluminum	45.7	45.7	NONE	—	—
Beryllium	1.0	1	B05WV7	0.46	0.46 U
			B05WV5	0.77	0.77 U
			B05WP5	0.52	0.52 U
			B05WT8	0.37	0.37 U
			B05WN9	0.25	0.25 U
			B05WP0	0.26	0.26 U
Calcium	321	321	NONE	—	—
Cadmium	1.4	1.4	NONE	—	—
Copper	5.1	5.1	NONE	—	—
Sodium	705	705	B05WV5	179	179 U
			B05WV8	205	205 U
			B05WV6	207	207 U
			B05WV9	249	249 U
			B05WW0	399	399 U
			B05WW4	480	480 U
			B05WW7	193	193 U
			B05WW6	229	229 U
			B05WW5	277	277 U
			B05WP5	277	277 U
			B05WP1	403	403 U
			B05WT8	182	182 U
			B05WV2	233	233 U
			B05WV3	283	283 U
			B05WT9	291	291 U
			B05WV4	405	405 U
			B05WP0	271	271 U
Lead	3.0	3.0	B05WW4	2.5 J	2.5 JU
			B05WW0	2.8 J	2.8 JU
			B05WW5	2.9 J	2.9 JU
			B05WP1	2.1 J	2.1 JU
			B05WV4	2.4	2.4 U
Vanadium	2.5	2.5	NONE	—	—

Table G-4. Radiochemistry Field Blank Evaluation Results.

Analyte Detected	Highest associated Field Blank Result pCi/L	Five-Times Field Blank Result pCi/g	Samples Affected	Sample Result pCi/g	Final Result pCi/g
Uranium-233/234	0.54	.0027	NONE	—	—
Uranium-238	0.56	0.0028	NONE	—	—
Carbon-14	540	2.7	B05WV7	0.25	0.25 U

**THIS PAGE INTENTIONALLY
LEFT BLANK**

DISTRIBUTION SHEET

To	From	Page 1 of 1
DISTRIBUTION	100 AREA REMEDIAL INVESTIGATION	Date 6-17-94

Project Title/Work Order	EDT No. 142067
Qualitiative Risk Assessment for the 100 HR-1 Source Operable Unit	ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
JM AYERS	H6-02	X			
RP HENCKEL	H6-02	X			
GS CORRIGAN	H4-16	X			
AD KING	H6-02	X			
SW CLARK	H6-01	X			
NK LANE	H6-01	X			
RL BIGGERSTAFF	H6-02	X			
EDMC	H6-08	X (1)			
CENTRAL FILES	L8-04	2			
ERC	H6-07	X			

**THIS PAGE INTENTIONALLY
LEFT BLANK**